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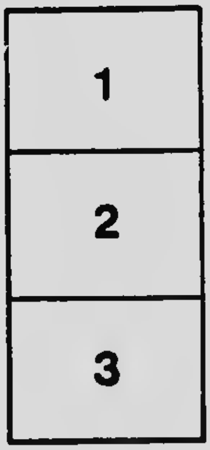
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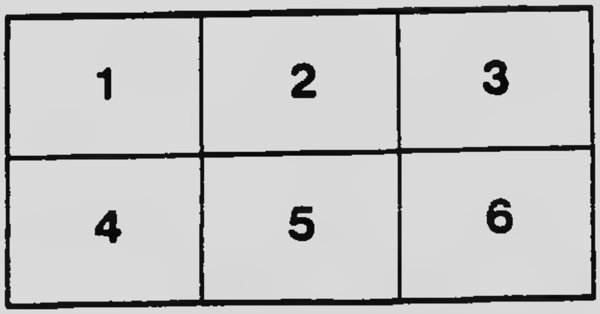
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CONGRÈS GÉOLOGIQUE INTERNATIONAL,
CANADA, 1913.

CONGRÈS GÉOLOGIQUE INTERNATIONAL

COMPTE-RENDU

DE LA

XII^E SESSION, CANADA

1913

OTTAWA
IMPRIMERIE DU GOUVERNEMENT
1914

PRÉFACE.

Lors de la réunion du Congrès géologique international à Vienne, en 1903, le Canada avait officiellement invité le Congrès à tenir sa dixième session dans ce pays. C'est au Mexique que devait revenir cet honneur La Xe session accepta l'invitation de la Suède pour la session suivante et décerna à la Belgique le droit d'inviter le Congrès pour sa XIIe session. Le 29 mai 1910 M. J. G. ANDERSSON, secrétaire général de la XIe session m'écrivit pour m'informer que la Belgique se trouvant pour diverses raisons dans l'impossibilité d'inviter le Congrès, l'avait prié de s'assurer s'il n'y eût pas un autre pays qui désirât le recevoir; et, sur ces entrefaites, il me demande si le Canada était encore disposé à offrir l'hospitalité au Congrès. Je fis part de cette lettre au très honorable Sir WILFRID LAURIER, premier ministre, à l'hon. CHAS. MURPHY, secrétaire d'État et à l'hon. WM. TEMPLEMAN, ministre des Mines, lesquels représentaient le gouvernement à cette époque à Ottawa, et ces messieurs me promirent un appui généreux de la part du gouvernement. Je consultai également Sir THOMAS SHAUGHNESSY, président du chemin de fer Canadien du Pacifique, et feu M. CHAS. M. HAYS, président du chemin de fer Grand-Tronc-Pacifique, qui ont offert le concours des chemins de fer; l'hon. FRANK COCHRANE, ministre des Mines de l'Ontario et M. W. G. MILLER, géologue provincial, qui me promirent l'appui de cette province; et M. FRANK D. ADAMS, professeur de géologie et doyen de la faculté des sciences appliquées à l'université McGill de Montréal, et président du Canadian Mining Institute, qui se déclara aussi en faveur de l'invitation. Le 2 juillet 1910 je câblai à M. ANDERSSON que le Canada se proposait d'inviter le Congrès pour sa XIIe session. Le 11 juillet, Sir RICHARD CARTWRIGHT, ministre des Mines intérimaire, envoyait une invitation officielle au nom du gouvernement canadien, et le département des affaires étrangères transmettait à la Grande-Bretagne une invitation qui devait être officiellement présentée au Congrès par l'envoyé extraordinaire britannique à Stockholm; de mon côté j'addressais une invitation officielle au nom de la Commission géologique, et le 15 juillet M. F. A. ADAMS faisait parvenir une invitation de la part du Canadian Mining Institute. Mais sur ces entrefaites, 28 juillet, le Congrès était invité par la Belgique à se réunir dans ce pays.

Lorsque nous fûmes informés que la Belgique se proposait de recevoir le Congrès, les choses étaient tellement avancées qu'il était devenu impossible pour le Canada de retirer son invitation laquelle avait été faite de bonne foi. Aussi les délégués belges au Congrès de Stockholm, en présence des démarches faites par le Canada, eurent l'amabilité de changer leur invitation et de la faire pour le XIIIe au lieu du XIIe Congrès, et c'est le Canada qui fut choisi comme lieu de réunion pour le XIIe Congrès.

Sous les auspices du gouvernement canadien, une assemblée de géologues et ingénieurs des mines représentant les institutions scientifiques qui avaient invité le Congrès, et les services des mines des diverses provinces fut tenue à Toronto le 2 décembre 1910. A cette assemblée le Comité exécutif fut nommé et chargé de la préparation du Congrès. On trouvera plus loin, au chapitre consacré à la préparation du Congrès, le compte-rendu des travaux de ce comité. Les membres du Comité exécutif ont droit aux remerciements du Congrès pour le temps et le soin qu'ils ont consacrés aux devoirs importants qui leur incombaient, et pour la façon remarquable dont ils s'en sont acquittés. On pourrait mentionner particulièrement M. F. D. ADAMS, le président, M. G. G. S. LINDSEY, qui a agi comme président à la fois du comité des finances et du comité des ressources houillères, dont l'expérience dans les affaires a été d'un service inestimable pour le Comité, et le secrétaire M. STANLEY LECKY.

Nous avons le plaisir de reconnaître les services rendus au Congrès par son Altesse Royale, FIELD-MARSHALL, LE DUC DE CONNAUGHT, Gouverneur général qui a bien voulu en accepter la présidence honoraire; par le très honorable Sir CHAS. FITZPATRICK, administrateur du Canada qui, en l'absence de son Excellence le Gouverneur général, accepta gracieusement de le représenter à l'ouverture de la session à Toronto; au gouvernement fédéral et aux gouvernements provinciaux; aux compagnies de chemin de fer; aux diverses sociétés minières; aux membres du Canadian Mining Institute; et aux chambres de commerce et fonctionnaires municipaux des endroits visités par le Congrès.

Le très honorable Sir ROBERT L. BORDEN, premier ministre et les autres représentants du gouvernement ont fait tout en leur pouvoir pour assurer le succès du Congrès, non seulement au moyen de leurs généreuses contributions aux dépenses de l'entreprise et l'intérêt qu'ils y ont porté, mais aussi en prenant la responsabilité des frais de publication de la monographie coûteuse des Ressources houillères mondiales, et en autorisant la Commission géologique à préposer à la préparation du Congrès tous ceux de ses fonctionnaires dont on pourrait avoir besoin, pour diriger les excursions et prendre part aux travaux de la session. C'est la Commission géologique qui a publié les Ressources houillères mondiales; elle a rédigé et publié également tous les livrets-guides sauf les numéros 6 et 7, de même que le Compte-Rendu, ce qui a économisé au Congrès de très fortes dépenses.

Les excursions comportaient le parcours de Sydney, Nouvelle-Ecosse à Victoria, Colombie britannique, et de la ligne frontière internationale à Mount St. Elias et Dawson, territoire du Yukon, en tout, au delà de 25,000 milles d'excursions à diriger officiellement entre le 13 juillet et le 5 octobre; par conséquent la préparation des livrets-guides et des détails des excursions a demandé beaucoup de temps de la part des fonctionnaires de la Commission. Il a fallu exécuter beaucoup de nouveaux travaux d'exploration pour combler certaines lacunes dans les connaissances existantes sur la géologie du pays, De ce fait les travaux réguliers de la Commission se sont trouvés accélés de plusieurs années et le Congrès dut tenir compte non seulement au gouvernement mais aux parties du pays où le besoin de travaux géologiques se faisait sentir, de la présé... accordée aux investigations du Congrès. Les livrets qui les représentent près de 1,700 pages compt... ment environ 150 cartes spéc..les et de nombreuses illustrations. Presque tous les membres du personnel de la Commission furent chargés de devoirs importants relatifs au Congrès. L'on ne peut pas ...entionner chaque individu pour sa part de mérite dans le succès de l'entreprise, mais les noms qui suivent seraient peut-être dignes d'une mention spéciale en ce qui concerne les excursions. M. G. A. YOUNG, qui s'est occupé de l'excursion maritime, des livrets-guides et de la session à Toront... M. C. CAMSELL, chargé de la publication ... ...vrets-guides, M. A. DICKSON, chargé de la préparation des cartes sp...ial... ; M. W. MCINNES membre du Comité exécutif et de tous les comités ... ...ublica-tion, ainsi que ses aides: M. D. B. DOWLING et feu M. W. W. LEACH chargés de la publication des Ressources houillères mondiales; et M. W. H. COLLINS, à qui é... ... confiée la publication des articles scientifiques pour le Compte-Rendu. Le gouvernement fédéral a mis également à la disposition du Congrès la collaboration de la division des Mines, dont le directeur M. EUG. HAANEL a fourni des publications spéciales et envoyé plusieurs membres de son personnel à titre de guides ou secrétaires de certaines excursions.

Le gouvernement d'Ontario a non seulement contribué très largement aux fonds du Congrès, ...ais par l'entremise du géologue provincial M. W. G. MILLER et de son ...sonnel, lui a épargné beaucoup de travail et de frais. Deux des livrets-g...ides ont été préparés et imprimés sous leur direction et, de plus, ils ont organisé et dirigé les principales excursions dans l'Ontario et participé aux travaux d'autres excursions.

Les gouvernements de Québec et de la ...olombie britannique ont tous les deux accordé de généreuses allocations a... ...ngrès, contribué aux travaux par l'entremise de leurs services provinciaux ... mines, et offert l'hospitalité aux membres étrangers. La Nouvelle-Écosse a aussi apporté son concours financier et fait aux excursionistes des Provinces maritimes une généreuse et cordiale réception.

Ce sont les excursions qui ont constitué la partie la plus importante du Congrès et leur succès devait dépendre de l'intérêt mis et de la coopération apportée par les compagnies de chemin de fer. Grâce à l'honorable FRANK COCHRANE, ministre des chemins de fer et canaux et aux administrateurs des compagnies Canadian Northern, Canadian Pacific, Grand Trunk, Grand Trunk Pacific et des chemins de fer de l'État, le service a été parfait à tous les points de vue. Afin de permettre aux membres d'employer aussi avantageusement que possible le temps consacré aux excursions, les horaires, particulièrement pour les excursions dans l'ouest, étaient minutieux et compliqués. Il est vraiment très remarquable qu'avec les énormes distances à parcourir et pendant un si long espace de temps, au milieu de la saison des voyages la plus active, on ait pu remplir un pareil programme de trains spéciaux sans le moindre accroc et sans avoir rien à changer aux horaires, et cela suppose une admirable habileté d'exécution. Le Congrès est également redevable au chemin de fer Canadian Northern d'une généreuse contribution en espèces sonnantes. L'on doit des remerciments au Canadian Pacific Railway, pour ce qui a été l'événement le plus saillant du Congrès c'est-à-dire l'excursion à la baie Yakutat, au fjord Russell et aux Alpes St.-Elias. Comme il n'y a pas de ligne de navigation régulière dans cette région, il eut été impossible d'y pénétrer si la compagnie Canadian Pacific n'eut pas retiré du service régulier, pendant sa saison la plus active, l'un des nouveaux et magnifiques paquebots de sa flotte côtière du Pacifique, pour le mettre obligeamment à la disposition du Congrès. C'est ainsi qu'il a été donné aux excursionistes de contempler le plus merveilleux panorama de montagnes au monde et peut-être le phénomène glaciaire le plus extraordinaire.

Le C.P.R. SS. *Princess Maquinna* en faisant ce voyage n'était que le deuxième vaisseau à pénétrer dans le fjord Russell; le premier ayant été le vaisseau explorateur de l'expédition Harriman.

Il ne faut pas publier les services rendus par l'honorable M. George Black, commissaire du Territoire du Yukon; c'est principalement grâce à ses efforts que l'on a pu jouir de toutes les commodités du voyage et d'une magnifique réception lors de l'excursion vers l'avant-poste sous-arctique de la civilisation.

Le président et le Conseil des gouverneurs de l'université de Toronto ont largement contribué au succès du Congrès en lui accordant l'usage des édifices de l'université, dont les salles spacieuses, ont avantageusement servi de bureaux et de lieux de réunion. D'autre part, les résidences et salles à manger permettaient aux membres de vivre en commun sur les lieux mêmes du Congrès, de façon à se trouver constamment en contact et pouvoir ainsi échanger leurs idées.

Nous devons les plus sincères remerciments au British Foreign Office et au service consulaire britannique dans toutes les parties du monde pour avoir si complaisamment participé aux recherches sur les ressources houillères mondiales, et aussi pour nous avoir aidés dans l'envoi des invitations au délégués étrangers dont la compétence et la distinction ont relevé l'éclat de cette réunion.

Un mot de remerciment enfin aux membres et délégués éminents qui sont venus au Congrès en si grand nombre et de pays si éloignés, pour leur courtoisie, leur patience et leur bonne humeur soit durant les assemblées ou au cours des excursions. Ils ont concouru autant que possible à faciliter le travail, très complaisamment fermé les yeux sur certaines lacunes ou mésaventures, et, de façon générale, se sont montrés de joyeux camarades avec qui c'était un véritable avantage de se rencontrer et s'associer, et à qui l'on éprouvait toujours un plaisir à rendre service. C'est à eux qu'il faut attribuer le succès remarquable du Congrès, et leur visite laissera un souvenir inoubliable au Canada parmi tous ceux qui ont eu le plaisir de les rencontrer.

RECETTES ET DÉPENSES.

Les comptes du Congrès sont à l'heure actuelle virtuellement tous soldés; on trouvera dans le bordereau ci-après un état des recettes et dépenses.

Dépenses.

Organisation; honoraires, frais de bureau, etc.	$17,907 27
Frais de voyage	3,691 41
Circulaires	3,331 16
Allocation pour la préparation des livrets-guides	1,817 45
Déficit sur les frais des excursions	23,509 27
Dépenses de la session	6,965 99
Divers	1,349 59
Argent déposé en banque	81 20
	$58,653 62

Recettes.

Gouvernement du Canada	$25,000 00
Gouvernement d'Ontario	7,000 00
Gouvernement de Québec	5,000 00
Gouvernement de la Colombie britannique	5,000 00
Gouvernement de la Nouvelle Ecosse	1,651 02
Chemin de fer Canadian Northern	5,000 00
Coniagas Mines Company, Limited	1 000 00
Mond Nickel Company, Limited	500 00
Canadian Copper Company	500 00
Hollinger Gold Mines, Limited	500 00
Canadian Collieries	350 00
Autres sociétés minières: LeRoi No. 2; Union Natural Gas; Seneca Superior; Cobalt Lake; Provincial Natural Gas; each, $50	250 00
P. Burns, Calgary	200 00
Cotisations du Congrès	4,922 54
Vente des livrets-guides	1,422 44
Intérêt des dépôts en banque	347 62
	$58,653 62

Comme il a été dit précédemment, les gros frais d'imprimerie, les préparatifs des excursions, etc., ont été payés par les gouvernements du Canada et d'Ontario. Les réceptions organisées par des groupes locaux durant les excursions ont également contribué à diminuer les dépenses et, en même temps que les généreuses allocations reçues, ont permis au Congrès d'organiser des excursions à des prix beaucoup inférieurs pour les congressistes à ce que leur eussent coûté des voyages réguliers, ainsi que le montre le déficit laissé par les excursions. De cette façon et grâce aux billets de demi-place accordés par les compagnies de chemin de fer, les visiteurs ont été à même de voir le pays non seulement beaucoup plus rapidement et agréablement, mais à beaucoup moins de frais que dans les conditions ordinaires, ce qui n'est pas sans importance dans un pays comme le Canada où la vie est si chère et les voyages si coûteux.

Tout a été mis en oeuvre pour que le Compte-rendu soit distribué moins d'un an après la date de la réunion et le present travail est la preuve du succès de ces efforts.

(Signé) R. W. Brock,
Secrétaire général et trésorier.

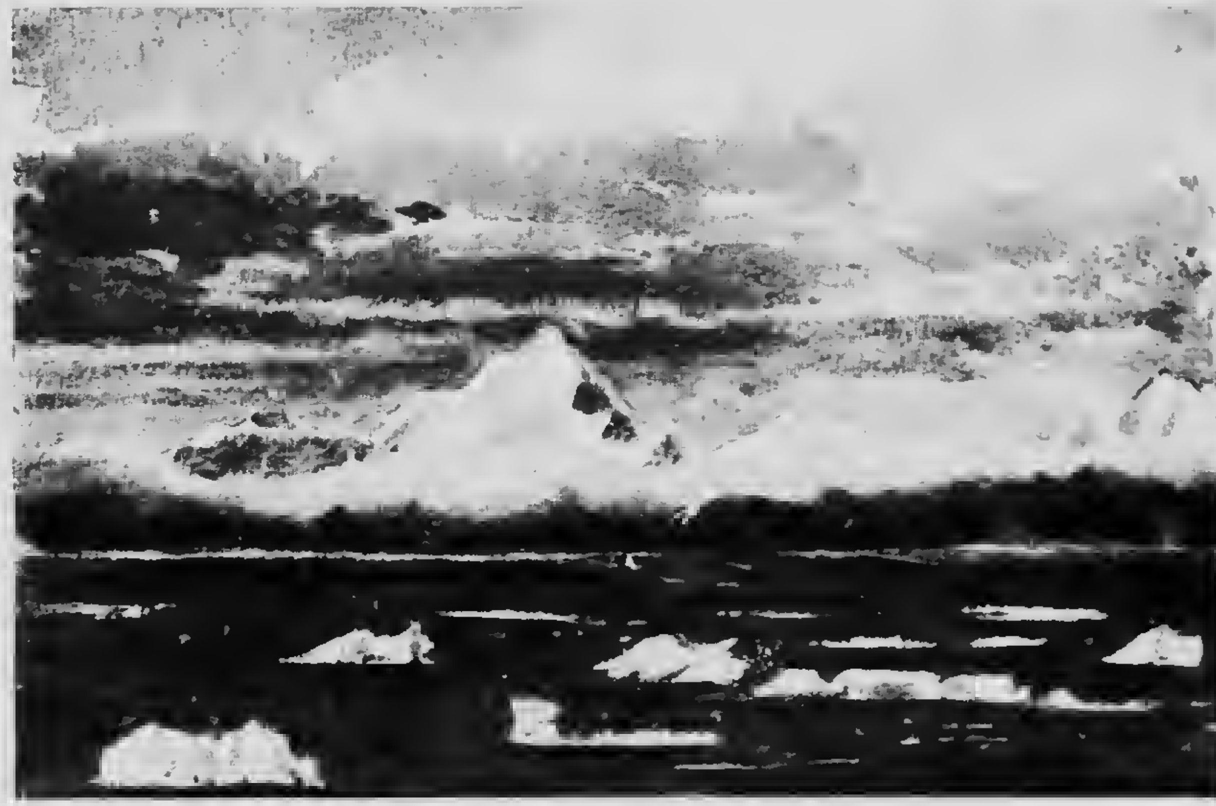
TABLE DES MATIÈRES.

Conférences et discussions pendant la Session.

Excursions.

Avant la session.

Pendant la session.



MONT ST. ELIAS.
D'après une aquarelle faite par H. M. CADELL, au cours de l'excursion A9, 1913

ERRATA.

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Page 1005, Fig. 1.; au lieu de *Atikokana* lisez *Atikokania.*

Après la session.

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PRÉPARATION DU CONGRÈS.

HISTORIQUE DU CONGRÈS.

Au cours de l'assemblée annuelle de la "American Association for the Advancement of Science", tenue à Buffalo au mois d'août 1876, une commission a été nommée pour préparer la convocation d'un Congrès géologique international à l'Exposition de Paris en 1878. Cette idée semble avoir pris naissance à ce moment là à la suite de l'inspection par des géologues, de cartes et coupes géologiques provenant de diverses parties d'Amérique et d'Europe, exposées cette même année à l'Exposition Internationale de Philadelphie. La première session du Congrès géologique international s'est donc tenue à Paris en 1878. Il y a eu depuis cette époque des sessions à tous les trois ou quatre ans dans bien des pays différents. Le tableau ci-joint est un relevé des sessions qui ont eu lieu jusqu'à ce jour.

RELEVÉ DES SESSIONS.

Session.	Année.	Pays	Vice-Présidents.	Délégations.	Membres Inscrits.	Membres Présents.	Pays Représentés.
1ème.	1878	France.	18	7	310		23
2ème	1881	Italie.	19	15	120	224	22
3ème.	1885	Allemagne.	20	13	155	262	22
4ème.	1888	Angleterre.	22	37	830	122	25
5ème.	1891	États-Unis.	31	30	546	251	26
6ème.	1894	Suisse.	15	14	401	273	20
7ème.	1897	Russie.	40	121	1,037	704	27
8ème.	1900	France.	46	61	1,016	464	30
9ème.	1903	Autriche.	25	42	661	393	31
10ème.	1906	Mexique.	32	52	707	321	34
11ème.	1910	Suède.	74	175	879	625	36
12ème.	1913	Canada.	72	362	981	467	49

OBJET ET TRAVAUX DU CONGRÈS.

L'objet du Congrès géologique international est, en peu de mots, de favoriser l'avancement des connaissances relatives à la terre, tant au point de vue de la science géologique pure, que de son application aux arts et industries, par l'association et la coopération des géologues les plus distingués de toutes les nations.

Les méthodes les plus importantes qu'il met en œuvre pour arriver à ses fins comportent des assemblées, publications, commissions internationales, excursions et prix à décerner.

Sessions.—Les sessions sont convoquées tous les trois ou quatre ans dans des pays différents, chaque session devant durer de sept à dix jours. A ces assemblées les principaux pays, sociétés et universités sont représentés par des délégués nommés à cette fin; on y lit des travaux traitant de questions d'intérêt général et l'on discute des sujets importants au point de vue géologique.

Publications.—Les délibérations du Congrès sont publiées le plus tôt possible après que la session s'est terminée. Elles contiennent les discussions et les communications les plus importantes, ainsi qu'un rapport général sur l'état financier et les travaux du Congrès.

Commissions internationales.—Des commissions sont organisées pour traiter des questions qui exigent une collaboration internationale, telles que: travaux de recherche d'intérêt général ou international, étalonnage des teintes et signes employés dans la confection des cartes géologiques, étalonnage de la nomenclature géologique et étude des projets de cartes géologiques générales.

Excursions.—Les excursions sont devenues une partie importante des sessions et toutes les facilités possibles sont mises à la portée des membres dans le pays où se tient l'assemblée pour leur permettre d'étudier sa structure géologique et ses ressources minérales à peu de frais et sous la direction de guides compétents.

On distribue pour les excursions des livrets-guides, qui ne servent pas seulement à guider l'excursioniste mais donnent généralement un bon aperçu de la géologie du pays où se tient le Congrès.

Prix.—Le Congrès pourvoit à la distribution de prix pour travaux spéciaux accomplis dans le domaine de la géologie. Le prix SPENDIAROFF fondé par M. SPENDIAROFF de St.-Pétersbourg, Russie, en mémoire de son fils, est décerné à chaque session pour le travail le plus important publié sur la tectonique depuis la session précédente. Il a été accordé au cours de différentes sessions des prix spéciaux.

ORGANISATION ET ADMINISTRATION DU CONGRÈS.

Conseil. Le Congrès est administré par un Conseil constitué comme suit:—

(a) Membres du Comité d'organisation de cette session du Congrès.

(b) Présidents en fonction de sociétés géologiques.

(c) Directeurs des grands services géologiques.

(d) Membres du Bureau (vice-présidents et autres officiers élus par les membres à leur première réunion).

(e) Membres du Congrès que le Conseil peut ajouter à la liste.

Bureau.—A la première assemblée de la session le Conseil soumet à l'approbation des membres une liste de noms pour constituer le "Bureau", qui sera chargé de préparer les ordres du jour pour les séances.

Le Secrétaire général et les officiers d'une session, qui composent le Bureau, sont responsables de l'administration générale des affaires du Congrès jusqu'à ce que leurs successeurs aient été nommés à la session suivante.[1]

Comité d'Organisation.—Un Comité d'organisation ou Comité exécutif, ou bien les deux, sont nommés par le gouvernement ou les institutions dont l'invitation pour la session suivante aura été accepté, afin de faire les préparatifs pour la session.

PRÉPARATIONS DE LA DOUZIÈME SESSION.

Le Congrès international géologique siégeant à Vienne en 1903 a été invité à tenir sa prochaine session au Canada; cette invitation a été réitérée à Stockholm en 1910, et cette demande etait appuyée par le Gouvernement canadien, la province d'Ontario, le Canadian Mining Institute et la Société Royale du Canada. L'invitation de se réunir au Canada en 1913 été acceptée.[2]

Sur les instances du directeur de la Commission géologique, agissant au nom du gouvernement, une assemblée des géologues et ingénieurs des mines représentant les institutions qui avaient invité le Congrès à se réunir au Canada s'est tenue à Toronto, le 2 decembre, 1910. Étaient présents à cette assemblée:—MM. F. D. ADAMS, M. B. BAKER, J. A. BANCROFT, R. W. BRIGSTOCK, R. W. BROCK, A. A. COLE, A. P. COLEMAN, E. DULIEUX, JAMES McEVOY, H. MORTIMER-LAMB, W. S. LECKY, G. G. S. LINDSEY, O. E. LEROY, F. LORING, R. G. McCONNELL, J. McLEISH, W. McNEILL, W. G. MILLER, J. C. MURRAY, W. A. PARKS, O. N. SCOTT, J. B. TYRRELL et T. L. WALKER.

Cette assemblée a élu un Comité exécutif choisi parmi les géologues[3] résidant dans la partie centrale du Canada, afin de procéder à l'organisation de la douzième session.

Le Comité exécutif s'est tout de suite mis à l'œuvre pour préparer la session et dès le printemps de 1911 a envoyé une circulaire préliminaire avec une liste d'excursions projetées.

Puis parurent à différents intervalles aux mois de mai, mars, mai et juin respectivement la première, deuxième, troisième et quatrième circulaire, dans lesquelles on donnait successivement des informations plus étendues au fur et à mesure que se complétaient les préparatifs pour la session.

Ces circulaires furent imprimées en français et en anglais et envoyées à plus de 16,000 géologues de toutes les parties du monde, d'après une liste compilée principalement sur les rôles d'inscription de sociétés géologiques.[4]

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[1] *Compte-rendu*, Paris, 1878, p. 271.

[2] *Compte-rendu*, XIe Session, Stockholm, 1910; Fasc. 1, p. 93.

[3] Pour les noms du Comité exécutif voir, p. 11.

[4] Nous publions à titre de renseignement, page 947 une liste de ces sociétés, dont la compilation comportait une somme considérable de correspondance et qui doit être à peu près complète. Relativement à la préparation de ces listes, comme pour ce qui concerne les informations recueillies au sujet des Ressources Houillères Mondiales, le Comité exécutif doit tout particulièrement reconnaître les bons services rendus par les divers bureaux du British Consular Service.

et aussi d'après la liste ayant servi pour les congrès précédents et diverses autres sources.

Première circulaire.—Cette circulaire donnait les sujets de discussion choisis et un programme général des projets d'excursion.

Deuxième circulaire.—La deuxième circulaire renfermait les noms des officiers; les principaux règlements qui devaient régir le Congrès, les matières à discuter, avec les noms de ceux qui s'étaient engagés à présenter des travaux, des détails sur les itinéraires des excursions (avec quatre cartes), et les dépenses à encourir de même que d'autres informations relatives au voyage jusqu'à Toronto et au logement dans cette ville.

Troisième circulaire.—La troisième circulaire donnait avec plus de details les mêmes informations que la deuxième. Elle contenait également des renseignements au sujet des privilèges sur les chemins de fer accordés aux membres du Congrès pendant leur séjour au Canada ainsi qu'une liste des transatlantiques voyageant au Canada et des agents de toutes les compagnies maritimes faisant le service au Canada.

Quatrième circulaire.—La quatrième circulaire qui n'a été distribué qu'aux membres du Congrès ou sur demande spéciale, renfermait le programme de la session qui devait se tenir à Toronto, des notices relatives aux commissions internationales, et aux propositions devant être soumises à la session, de même que les noms des personnes qui s'étaient engagées à fournir des travaux.

Le Comité exécutif à tenu dix-huit assemblées avant la session: une en 1910, trois en 1911, sept en 1912 et sept en 1913.

Il a été décidé en janvier 1912, que le poste de secrétaire exigeait tout le travail d'un homme; et le 23 janvier M. W. S. Lecky fut nommé Secrétaire du Comité exécutif, avec un engagement de deux ans. Depuis cette époque M. Lecky a consacré tout son temps à remplir ses fonctions, agissant virtuellement en qualité de directeur sous les ordres du Comité, et l'on ne peut que reconnaître très hautement son zèle dans l'accomplissement de ses devoirs.

Vers la fin de 1912, un grand Comité d'organisation a été choisi par le Comité exécutif afin de s'occuper des préparatifs généraux. Les principales fonctions de ce Comité plus nombreux consistaient dans la formation de comités locaux au principaux endroits à visiter au cours des excursions, et dans l'obtention de fonds pour subvenir aux dépenses du Congrès.[1]

Les bureaux principaux furent établis aux bureaux de la Commission géologique au Musée commémoratif Victoria à Ottawa, jusqu'au 2 août, alors qu'ils furent transférés à l'Université de Toronto où la session a eu lieu. Pour l'avantage des membres arrivant à Montréal, on a tenu un bureau-succursale à la "McGill Student's Union," Montréal du 10 juillet au 6 août, veille de l'ouverture de la session à Toronto. On a également ouvert un bureau provisoire à l'hôtel Empress, Victoria, Colombie Britannique, le 26 août, quand les deux excursions transcontinentales s'y sont rencontrées.

[1] Pour les noms du Comité d'organisation voir p. 10.

Le travail du Comité, au fur et à mesure qu'il devenait plus compliqué a été de temps à autre réparti entre plusieurs sous-comités auxquels on a adjoint dans certains cas des membres ne faisant pas partie du Comité exécutif. Les plus importants de ces comités étaient les suivants:

Comité des Ressources Houillères: G. G. S. LINDSEY, président; W. McINNES, secrétaire; F. D. ADAMS, R. W. BROCK, D. B. DOWLING, CHARLES FERGIE, JAMES McEVOY et J. B. PORTER. Ce comité était chargée de préparer une monographie sur *The Coal Resources of the World*, sous la présidence de M. G. G. S. LINDSEY.

En mai 1911, une circulaire fut préparée par le Comité demandant des informations et établissant la forme suivant laquelle la classification des houilles et le relevé des réserves devraient être présentés, ainsi que les formules pour la mise en tableaux. La circulaire, avec les formules accompagnée d'une lettre spécifiant la longueur approximative que devait avoir chacun des rapports, fut envoyée par le Secrétaire général, M. BROCK aux divers services géologiques et bureaux des mines de toutes les parties du monde, et, dans certains cas, à des spécialistes particuliers. Les personnes invitées à envoyer des rapports s'y prêtèrent très obligeamment; mais, dans bien des cas, il fallait une certaine somme de travail sur le terrain pour obtenir les renseignements nécessaires, et par suite, les informations complètes que comportaient les rapports ne furent obtenus qu'à la suite de longs et persistants efforts. Le dernier rapport est arrivé en mai 1913.

La Commission s'est ensuite occupée de nommer des rédacteurs.

Dans la préface de cette monographie il a été dit par inadvertance que la "*préparation*" de ce travail avait été confiée à la Commission géologique du Canada; c'est la "*rédaction*" qu'il aurait fallu dire. Le 7 mars 1912, le Comité des ressources houillères avait recommandé que MM. W. McINNES et D. B. DOWLING fussent nommés rédacteurs; cette nomination fut confirmée par le Comité exécutif à son assemblée du 8 mars. Plus tard M. W. W. LEACH fut adjoint à ces messieurs. Un certain nombre d'autres membres prirent également part à ce travail, particulièrement pour ce qui concernait la mise en tableaux, la lecture des épreuves, les cartes et les illustrations.

Le Comité eut ensuite à prendre une décision au sujet de la publication, et l'on s'aperçut qu'il était très difficile de s'entendre avec un éditeur pour l'exécution d'un ouvrage aussi volumineux et aussi coûteux en si peu de temps.

Le 12 octobre 1912, lors de sa neuvième séance, le Comité exécutif autorisa le Comité des ressources houillères à s'occuper directement de la publication de la monographie sans l'intervention du Comité des publications.

A la suite de pourparlers avec diverses maisons de publication, la Commission confia ce travail à la maison Morang & Company, Limited, 145 rue Wellington Ouest, Toronto, ce qu'elle ne pût faire que grâce à la générosité du gouvernement canadien qui se rendit garant envers la compagnie de publication en cas de perte.

C'est particulièrement aux démarches de son président et de M. BROCK, directeur de la Commission gé ique que ce comité doit d'avoir pu arriver à conclure ces arrangements.

Les volumes ont été imprimés par la Murray Printing Company, Limited, de Toronto. Le contrat de publication a été signé le 27 décembre 1912, et l'ouvrage est paru au milieu de juillet, 1913.

2. *Comité des Excursions:* R. W. BROCK, O. E. LEROY. Ce comité était chargé de l'organisation des excursions, dont les itinéraires avaient été fixées par le Comité exécutif. Le comité des excursions régla de concert avec les chefs et guides, le détail des itinéraires, et les arrangements ainsi réglés ont été acceptés presque sans changements par les compagnies de chemin de fer.

3. *Comité des Finances:* G. G. S. LINDSEY, président; F. D. ADAMS, R. W. BROCK, W. G. MILLER, J. B. TYRRELL. Ce comité, formé au commencement de 1911, s'est chargée de la question importante des finances du Congrès. Cette charge comportait une lourde responsabilité et c'est au travail ardu de son président qu'il faut attribuer en grande partie le résultat que l'on peut voir dans la liste des contributions et les bordereaux du Congrès dans la préface. Le Comité des finances a été aidée par un groupe de soixante-dix conseillers honoraires.

4. *Comité des Publications:* A. E. BARLOW, président; R. W. BROCK, C. CAMSELL, A. P. COLEMAN, W. H. COLLINS, T. C. DENIS, A. DICKISON, O. E. LEROY, W. MCINNES, W. G. MILLER, G. A. YOUNG. Ce comité, formé au commencement de 1911, a dirigé la publication des diverses circulaires et décidé quelle serait la forme et le contenu des livrets-guides. La rédaction des livrets-guides, qui ont été publiés par la Commission géologique a été commencée par M. MCINNES et continuée par M. CHARLES CAMSELL qui a dû faire la majeure partie de l'ouvrage. Les cartes accompagnant les livrets-guides ont été faites sous la direction de M. A. DICKISON, dessinateur à la Commission géologique, dont l'habilité et le zèle dans l'accomplissement de ce travail ont rendu possible l'exécution de la série de 140 cartes dans le peu de temps dont il pouvait disposer.

5. *Comité des Voyages:* G. G. S. LINDSEY, président; O. E. LEROY, R. W. BROCK. Ce comité s'est chargé de faire tous les arrangements nécessaires pour les voyages, et a obtenu pour les membres le privilége de voyager à demiplace qui leur avait été promis.

6. *Comité de Rédaction:* R. W. BROCK, W. H. COLLINS, W. MCINNES. Ce comité a été formé vers la fin de l'année 1912 pour s'occuper d'editer les études et propositions présentées durant la session. A la fin de la session la rédaction du compte-rendu a été confiée à MM. MCINNES et COLLINS.

7. *Comité des Sujets de Discussion:* A. E. BARLOW, A. P. COLEMAN, W. A. PARKS. Ces messieurs étaient chargés de recommander les sujets à discuter au cours de la session.

Comité local de Toronto: A. P. COLEMAN, président; W. A. PARKS, secrétaire; A. G. BURROWS, le président FALCONER, W. F. FERRIER, P. E. HOPKINS, R. E. HORE, H. L. KERR, C. W. KNIGHT, G. G. S. LINDSEY, J.

McEvoy, A. McLean, W. H. McNairn, W. G. Miller, A. L. Parsons, J. B. Tyrrell, Sir Edmund Walker, T. L. Walker, A. B. Willmott.

Ce comité a obtenu de l'Université l'usage des salles de réunion pour la session du Congrès, a organisé les excursions faites dans le voisinage de Toronto au cours de la session; pris les arrangements nécessaires pour l'assemblée d'ouverture, la conférence populaire, le banquet, la séance spéciale de l'Université, et, en un mot, s'est chargé de toutes les démarches locales préliminaires pour la session à Toronto.

Comité des dames à Toronto: Miss Helena Coleman, présidente, Mme. J. B. Tyrrell, vice-présidente, Mme. W. A. Parks, secrétaire.

Ce comité s'est occupé de recevoir et loger les dames du Congrès, en leur procurant et meublant des chambres convenables à l'Université et en les recevant à un luncheon dans les salons du speaker aux édifices du Parlement.

Ce comité s'est également efforcé de rendre le séjour agréable à tous les membres du Congrès, en offrant le thé tous les après-midi dans le carré de l'Université.

Il y avait en outre d'autres sous-comités s'occupant de patronage, invitations officielles, chefs de discussion et publicité.

Finances.—Les dépenses occasionnées par la session ont été défrayées à même le fonds général. C'est le gouvernement canadien qui a le plus contribué à ce fonds, mais il y a eu également des subventions accordées par plusieurs des provinces, des compagnies minières et des particuliers. Bien que les membres aient dû payer leur pension à l'Université de Toronto et au cours des excursions, l'on pourra voir par les bordereaux qu'il y a eu deficit dans ces deux cas, particulièrement au compte des excursions.

Délégations.—Les principaux gouvernements du monde, sociétés intéressées à la géologie et aux mines, universités et colléges ont été invités à envoyer des délégués à la session et en réponse à ces invitations 362 institutions se sont fait représenter par 307 délégués.

Inscription.—981 membres s'etaient fait inscrire et 467 étaient présents à la session de Toronto.

SESSION.

La session du Congrès s'est tenue à l'Université de Toronto du 7 août au 14 août. Les édifices de l'université mis généreusement à la disposition du Congrès constituaient un local magnifique pour la session. Les salles de conférences convenaient très bien aux réunions des diverses sections, et le Comité exécutif fut à même de mettre les dortoirs à la disposition des membres, ce qui leur permettait de se loger à bon marché et à proximité des salles de réunions.

Il a été remis au Comité 84 communications scientifiques pour être présentées à la session. De ce nombre 64 sont publiées dans une autre partie de ce volume.

Excursions.—Des excursions allant du bord de l'Atlantique à l'est, au Pacifique à l'ouest furent organisées afin de permettre aux membres de se familiariser avec les problèmes géologiques qui se présentent au Canada, du moins sous leurs aspects généraux, et de se rendre compte par eux-mêmes quelles sont les ressources naturelles, minérales ou autres, de ce pays. On trouvera plus loin dans cet ouvrage les comptes-rendus de ces excursions.

RÈGLEMENTS GÉNÉRAUX CONCERNANT LA XIIE SESSION.

Les règlements suivant avaient été adoptés avant l'ouverture de la session:

Inscription.—Il n'est exigé aucun titre professionnel pour devenir membre. Les membres ont le droit de prendre part aux assemblées et discussions à Toronto, et de recevoir après la session un exemplaire du *Compte-Rendu*. Les membres ayant le droit de participer aux excursions sont indiqués sous la rubrique "Excursions."

Les livrets-guides ne seront pas vendus aux membres autrement qu'en séries complètes, au prix de $2.50 par série. Chaque membre n'aura droit qu'à une seule série. Pour toute personne autre que les membres le prix est de $7.50.

Monographie sur les ressources houillères.—La monographie sur les *Coal Resources of the World* sera publiée sous forme de trois volumes in-quarto avec carton-atlas. Le prix pour le public en sera de $25.00 l'ouvrage complet. Aux membres, chaque série se vendra $20.00 pourvu que la commande soit donnée à l'éditeur ou au Secrétaire avant le 16 août 1913.[1]

Mémoires et Propositions.—

(a) Les titres des mémoires, notes et propositions à être lus doivent être envoyés au Secrétaire général le plus tôt possible.

(b) Les auteurs sont priés d'indiquer si leurs contributions seront illustrées au moyen de vues stéréoscopiques ou accompagnées de spécimens ou cartes.

(c) Le temps accordé pour la présentation de chaque mémoire est limité à vingt minutes, à moins que le Comité n'accorde un supplément de temps.

(d) Les mémoires et propositions doivent être remis aux mains du Secrétaire général pour le 1er mai si l'on désire qu'ils soient imprimé à temps pour être distribués avant la réunion. Il sera impossible de fournir des épreuves d'imprimerie aux auteurs et, par conséquent, les manuscrits doivent être dactylographiés et l'on doit s'attacher avec le plus grand soin à l'exactitude de tous les détails, comme ponctuation, emploi des lettres majuscules, italiques, etc.

(e) La langue officielle du Congrès est le français, mais les communications et mémoires peuvent être présentés en français, en anglais ou en allemand.

(f) Les auteurs sont priés de fournir en même temps que leurs mémoires,

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[1]On aurait dû spécifier dans les circulaires qui ont été distribuées que le prix du volume du *Compte-Rendu* comprenait le port; mais que pour la monographie et les livrets-guides les prix étaient nets, et qu'il fallait payer le port en plus.

des résumés, de préférence en anglais ou en français. Les résumés ne doivent pas dépasser cinq pour cent de la teneur du travail lui même.

(g) L'Exécutif ne se charge pas des traductions.

(h) L'acceptation d'une contribution et sa publication avant la réunion n'impliquent pas qu'elle sera publiée dans le *Compte-Rendu.*

Excursions.—

(a) Il n'y a pas de restriction dans la participation au Congrès géologique international, mais les excursions seront limitées aux membres du Congrès qui sont géologues, ingénieurs des mines, géographes et aux autres personnes qui se livrent à l'étude ou à l'application d'une branche quelconque de la géologie.

(b) Des dispositions seront prises, si c'est possible, pour permettre aux femmes des membres du Congrès de participer aux excursions. Ce privilège ne peut pas s'étendre en général aux autres parents ou amis des membres.

(c) Si l'on désire faire des arrangements préliminaires, on doit en faire la demande par écrit sur le formulaire fourni à cette fin, et accompagner cette demande du dépôt spécifié. Si un membre se trouve dans l'impossibilité de prendre part à une excursion, son dépôt lui sera remis à condition que le Secrétaire reçoive avis de l'annulation de l'inscription le ou avant le 15 juin; si l'excursion est contremandée, le dépôt pourra être remis après cette date. Le paiement intégral pour chaque excursion doit se faire d'avance aussitôt que possible après l'arrivée au Canada.

Paiements.—Les paiements doivent être faits par mandats-poste ou par traite sur la Royal Bank of Canada. Les chèques ne sont pas acceptés.

COMPTES.

Au moment d'aller sous presse le bordereau final n'est pas encore prêt, mais l'état donné dans la préface est matériellement exact.

Les comptes ont été apurés tous les trois mois et des bordereaux ont été présentés à la suite de chaque vérification.

En raison des fortes contributions versées par le gouvernement fédéra et les gouvernements provinciaux et par des particuliers qui ont fourni leur temps ou leur matériel, cet état de compte ne donne qu'un faible aperçu des dépenses totales du Douzième Congrès en Canada.

En outre des nombreuses dépenses qui ont été épargnées au Congrès, un bureau a été mis durant deux ans, gratuitement à la disposition du bureau d'organisation à Ottawa avec l'usage du téléphone. Les délibérations (Compte-Rendu) sont publiées par la Commission géologique du Canada sans frais pour le Comité.

La correspondance dans les limites du Canada s'est échangée franc de port. Les livret-guides ont été imprimés et préparés par la Commission géologique et le Bureau des Mines d'Ontario, et ces services ont fait aussi tous les arrangements nécessaires pour les excursions; l'article de ce premier compte figurant dans l'état des dépenses ne couvre que des frais de peu d'importance pour les travaux que la Commission géologique ne pouvait pas entreprendre elle-même.

Les bureaux du siège principal de la Session à Toronto ont été fournis gratuitement par l'université de Toronto et ceux de Montréal, avant la Session, par l'université McGill.

En outre, le Comité doit des remerciements aux maisons de commerce suivantes qui ont gracieusement mis à sa disposition les articles ci-dessous mentionnés:—

"Office Specialty Manufacturing Company, Limited, Toronto:" ameublement de bureau pour la session à Toronto.

"United Typewriter Company, Limited, Toronto:" machines à écrire, pour la session à Toronto et pour les excursions.

"American Bank Note Company, Ottawa:" cartes d'invitation et de remerciements gravées sur acier.

"Canadian Fairbanks-Morse Company, Limited, Ottawa et Toronto:" coffre-forts pour les bureaux d'Ottawa et de Toronto.

Le Comité désire exprimer sa profonde reconnaissance pour toutes ces contributions et autres de même nature, ainsi que pour tous les versements en argent faits par les gouvernements, les compagnies minières et les particuliers dont les noms sont mentionnés à l'état inclus dans la préface.

COMITÉ D'ORGANISATION.

J. A. Allan, Edmonton; Henry M. Ami, Ottawa; M. B. Baker, Kingston; J. A. Bancroft, Toronto; D. D. Cairnes, Ottawa; Charles Camsell, Ottawa; Arthur A. Cole, Cobalt; Eugene Coste, Calgary; D. B. Dowling, Ottawa; J. A. Dresser, Sault Ste. Marie; E. Dulieux, Montreal; R. D. Falconer, Toronto; E. R. Faribault, Ottawa; W. F. Ferrier, Toronto; W. L. Goodwin, Kingston; R. P. D. Graham, Montreal; Aimé R. Gumont, Quebec; Eugene Haanel, Ottawa; E. Haycock, Wolfville; Robt. R. Hedley, Vancouver; Elfric D. Ingall, Ottawa; R. A. A. Johnston, Ottawa; Joseph Keele, Ottawa; E. M. Kindle, Ottawa; C. W. Knight, Toronto; H. Mortimer-Lamb, Montreal; Lawrence M. Lambe, Ottawa; William W. Leach, Ottawa; G. F. Matthew, St. John; Richard G. McConnell, Ottawa; James McEvoy, Toronto; John McLeish, Ottawa; W. Nicol, Kingston; J. B Porter, Montreal; W. Fleet Robertson, Victoria; Frederic H. Sexton, Halifax; J. T. Stirling, Edmonton; T. L. Walker, Toronto; Robert C. Wallace, Winnipeg; James White, Ottawa; A. B. Willmott, Toronto; George A. Young, Ottawa; and the members of the Executive Committee.

COMPOSITION DU CONGRÈS.

COMITÉ EXÉCUTIF.

Président d'honneur: Son Altesse royale le DUC DE CONNAUGHT, Gouverneur Général du Canada.

Vice-Présidents d'honneur:

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L'Honorable LOUIS CODERRE, Secrétaire d'État, Ministre des Mines.

L'Honorable FRANK COCHRANE, Ministre des Chemins de Fer et Canaux.

L'Honorable W. H. HEARST, Ministre des Terres, Forêts et Mines d'Ontario.

L'Honorable CHARLES DEVLIN, Ministre de la Colonisation, des Mines et Pêcheries de Québec.

L'Honorable Sir RICHARD MCBRIDE, Premier Ministre et Ministre des Mines de la Colombie Britannique.

L'Honorable E. H. ARMSTRONG, Commissaire du Travail et des Mines de la Nouvelle-Écosse.

Président: F. D. ADAMS.

Secrétaire général: R. W. BROCK.

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Président: F. D. ADAMS.

Secrétaire général: R. W. BROCK.

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Chine: P. WONG.
Danemark: O. B. BØGGILD, V. MADSEN.
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Soudan: G. W. GRABHAM.
Suède: H. BÄCKSTROM, H. SJÖGREN.
Terre-Neuve: J. P. HOWLEY.
Tunisie: P. WEISS.

Présidents des séances scientifiques: H. BÄCKSTROM, L. BALDACCI, T. C. CHAMBERLIN, K. INOUYE, W. LINDGREN, L. LÓCZY DE LÓCZ, E. DE MARGERIE, Sir H. MIERS, J. J. SEDERHOLM, G. O. SMITH, G. STEINMANN, A. STRAHAN, P. M. TERMIER, TH. TSCHERNYSCHEW.

DÉLÉGATIONS.

Allemagne.

Deutsche Reichsregierung: G. Steinmann (Leiter), A. Bergeat, H. E. Boeke, F. Frech, P. J. Krusch, L. Milch, W. Paulcke, A. Penck, H. W. Stille, T. F. W. Wolff.

Deutsche Geologische Gesellschaft, Berlin: P. J. Krusch.

Deutsche Mineralogische Gesellschaft, Jena: A. Bergeat.

Freiberger Geologische Gesellschaft, Freiberg: R. Beck.

Geographische Gesellschaft Greifswald, Greifswald: L. Milch.

Geologisches Institut der Königlich Preussischen Technischen Hochschule, Aachen: A. Dannenberg.

Geologisch-Palaeontologisches Institut der Rheinischen Friedrich-Wilhelms-Universität, Bonn: N. Tilmann.

Geologische Vereinigung, Marburg: G. Steinmann.

Gesellschaft zur Beförderung der gesamten Naturwissenschaften, Marburg: K. Andrée.

Grossherzoglich Badische Technische Hochschule Fridericiana, Karlsruhe: W. Paulcke.

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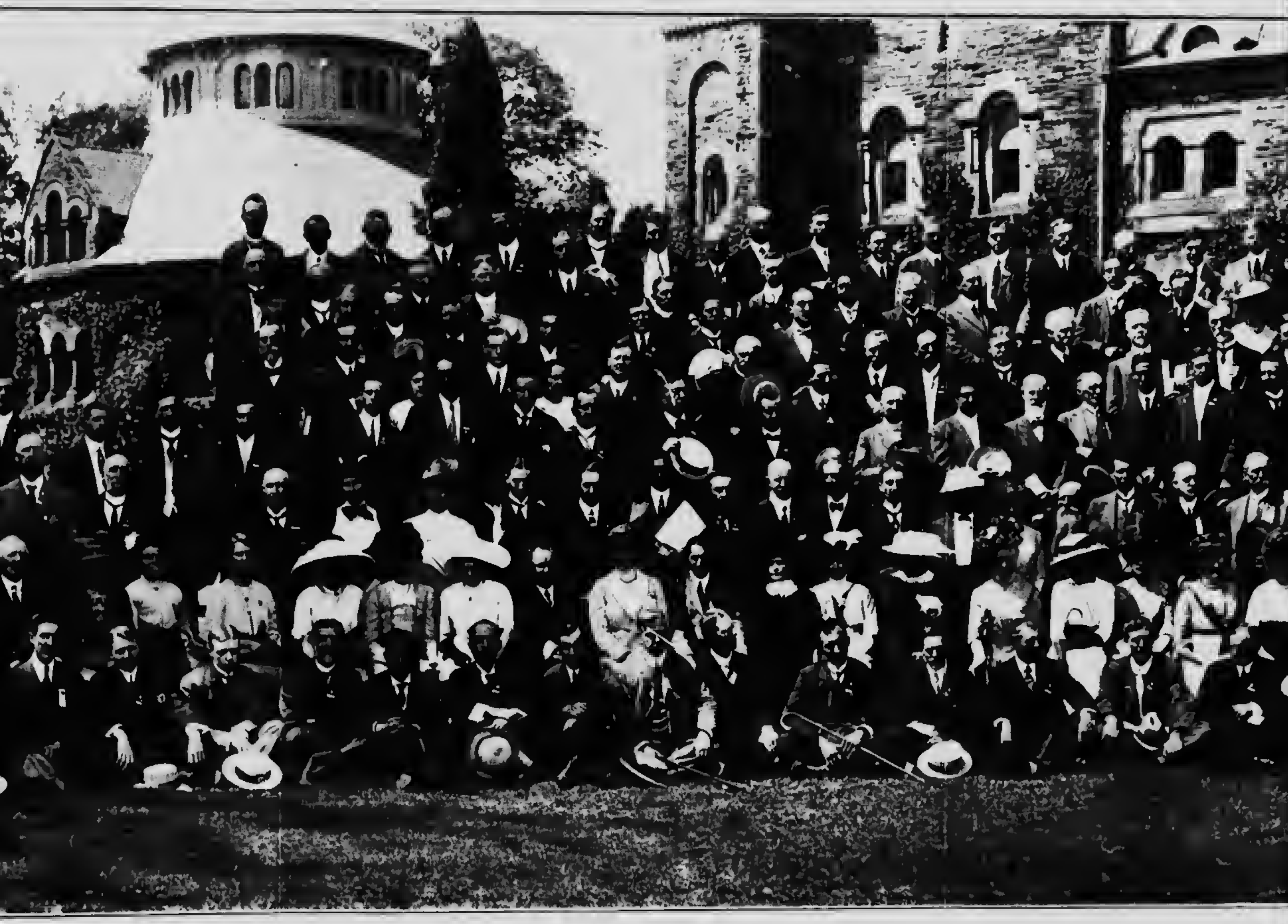

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Sociedad de Geografia Commercial de Barcelona .... Espagne
Sociedad de Ingenieros .... Pérou
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Sociedad Mexicana de Geografia y Estadistica, Mexico .... Mexique
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Williams, M. Y. .... Canada
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Young, G. A. .... Canada
Zealley, A. E. V. .... Rhodésie
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Zimmermann, E. .... Allemagne
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Zuber, R. .... Autriche-Hongrie

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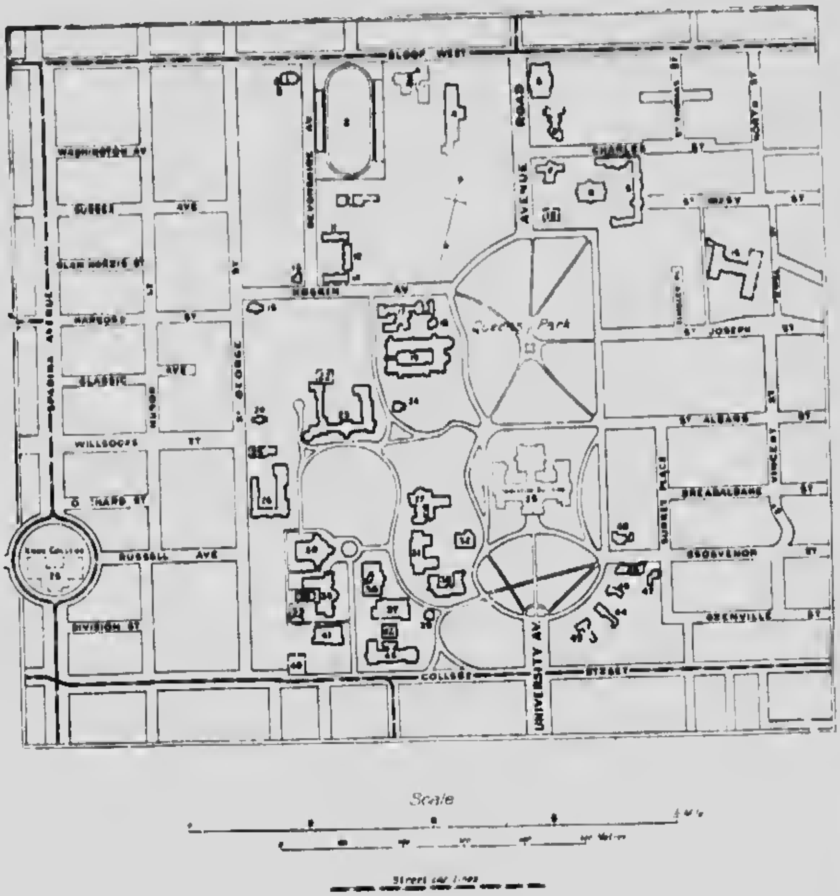
* Dans certains cas, deux ou plusieurs institutions de différents pays sont representées par le même délégué, reduisant ainsi ce total.



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UNIVERSITY OF TORONTO AND VICINIT'

PROGRAMME DU CONGRÈS.

DOUZIÈME SESSION, TORONTO, 7-14 AOÛT, 1913

Mercredi 6 Août.

8h. du soir. Réunion des membres du Congrès à l'Université de Toronto, sur l'invitation du Comité local de Toronto (costume de voyage). L'honorable WILLIAM H. HEARST, Ministre des Terres, Forêts et Mines, souhaite la bienvenue aux congressistes au nom de la province d'Ontario et du Comité Local.

Jeudi 7 Août.

SÉANCES SCIENTIFIQUES.

9h. du matin. Séance du Conseil.[1] (Salle N° 16, edifice No 23.)

10h. du matin. Réunion des Commissions internation[illegible] des

Midi. Ouverture générale du Congrès, Salle des facultés (édifice N° 30). Son Excellence le Trè[illegible] Hono[illegible] Sir CHARLES FITZPATRICK, P.C., G.C.M.G. Juge [illegible] de la Cour Suprême du Canada, Administrate[illegible] l'absence de Son Altesse royale le DUC DE CONNAUGHT, K.G., P.C., K.T., K.P., G.M.B., G.C.S.I., [illegible] G.C.I.E., G.C.V.O., Gouverneur général du [illegible] occupe le fauteuil de la présidence et, dans une [illegible] de bienvenue, déclare ouverte la session du Cong[illegible]

La bienvenue au Canada est souhaitée aux mem[illegible] du Congrès par l'honorable GEORGE W. PERLEY, faisan[illegible] fonctions de Premier Ministre, au nom du Gouvernemen[illegible] canadien; par l'honorable W. H. HEARST, Minis[illegible] des Terres, Forêts et Mines, au nom de la province d[illegible] Ontario; par M. le Maire HOCKEN, au nom de la ville

[1]Dans cette réunion constituante, le Conseil se compose des
Membres du Comité de fondation,
Membres du Comité d'organisation,
Présidents actuels des sociétés géologiques,
Directeurs des grands services géologiques.
Le Conseil s'adjoint en plus les
Membres du Bureau du Congrès,
Membres du Congrès que le Conseil appellera à siéger dans son sein

Toronto; et par M. le Président R. A. FALCONER, au nom de l'Université de Toronto.

M. TIETZE, Ancien président, prononce ensuite un discours de circonstance.

M. BACKSTROM, délégué du Gouvernement royal de Suède et représentant les officiers du XIe Congrès, dépose ses fonctions.

M. BROCK, aux lieu et place du Secrétaire général du XIe Congrès, annonce la composition du Bureau du Congrès et la soumet à l'approbation de l'assemblée.

M. ADAMS, Président du XIIe Congrès, occupe le fauteuil de la Présidence et prononce une allocution.

M. BROCK, Secrétaire général, fait connaître les mesures préparatoires prises par le Comité exécutif.

La monographie, *The Coal Resources of the World*, est présentée au Congrès par le Secrétaire général.

3h. du soir. Séance générale. Sujet No. 1. Les ressources houillères mondiales. (Salle des facultés, édifice N° 30).

DIVERTISSEMENTS.

4-6h. du soir. Le Comité des dames de Toronto offre un thé dans le carré de l'Université. (Édifice N° 23).

8h. du soir. M. EMMANUEL DE MARGERIE, Ancien président de la Société géologique de France, fait une conférence populaire sur la Carte géologique du monde.

Vendredi 8 Août.

EXCURSIONS.[1]

B 3. Grimsby et Hamilton. (Principalement paléontologique.)
B 10. Madoc. (Précambrien.)

SÉANCES SCIENTIFIQUES.

9h. du matin. Séance du Conseil. (Salle 8, édifice N° 23.)

9.30h. du matin. Réunion de la Commission du Prix Spendiaroff. (Salle 67, édifice N° 23.)

Réunion de la Commission pour la création d'une Revue internationale de géologie, paléontologie et pétrographie.

Réunion de la Commission de la "Palaeontologia Universalis." (Salle 65, édifice N° 23.)

[1] La description des excursions se trouve au chapitre "Excursions du Congrès."

Réunion de la Commission internationale pour l'étude de l'homme fossile. (Salle 13, édifice N° 23.)

Réunion de la Commission pour la création d'un lexique de stratigraphie. (Salle 27, édifice N° 23.)

Réunion de la Commission internationale des glaciers. (Salle 59, édifice N° 23.)

10h. du matin. Séance générale. Communications diverses. (Édifice N° 35.)

1. H. KEIDEL. *Über das Alter, die Verbreitung und die gegenseitigen Beziehungen der verschiedenen tektonischen Struktur in den argentinischen Gebirgen.*

2. G. A. F. MOLENGRAAFF. *Folded mountain chains, overthrust sheets and block-faulted mountains in the East Indian Archipelago.*

3. L. E. GENTIL. *La géologie du Maroc.*

2.30h. du soir. Séance de la Section 1. Sujet N° 2. Différentiation dans les magmas ignés. (Salle 8, édifice N° 23.)

1. R. A. DALY. *Sills and laccoliths illustrating petrogenesis.*

2. ALFRED HARKER. *Fractional crystallization the prime factor in the differentiation of rock magmas.*

3. JOSEPH P. IDDINGS. *Some examples of magmatic differentiation and their bearing on the problem of petrographical provinces.*

4. HENRY S. WASHINGTON. *The volcanic cycles in Sardinia.*

5. WILLIAM H. HOBBS. *Variations in composition of politic sediments in relation to magmatic differentiation.*

2.30h. du soir. Séance de la Section 3. Sujet N° 6. Périodes interglaciaires. (Salle 11, édifice N° 23.)

1. G. W. LAMPLUGH. *The inter-Glacial problem in the British Islands.*

2. A. P. COLEMAN. *An estimate of post-Glacial and inter-Glacial time in North America.*

3. G. F. WRIGHT. *Recent date of the attenuated glacial border in Pennsylvania.*

4. WARREN UPHAM. *The Sangamon inter-Glacial stage in Minnesota and westward.*

5. W. WOLFF. *Glazial und Interglazial in Norddeutschland.*

6. WILLIAM C. ALDEN. *Early Pleistocene glaciation in the Rocky mountains of Glacier National Park, Montana.*

DIVERTISSEMENTS.

9.30h. du matin et 2.30h. du soir. La ville de Toronto met des automobiles à la disposition des congressistes pour visiter les différents points intéressants de la ville.

1.30h. du soir. Le Comité des dames de Toronto offre un "lunch" aux dames congressistes dans les "salons de l'orateur," aile ouest des édifices du Parlement. (Édifice N° 28.)

4-6h. du soir. Le Comité des dames de Toronto offre un thé dans le carré de l'Université. (Édifice N° 23.)

Samedi 9 Août.

EXCURSIONS.

B 5. Moraines au nord de Toronto. (Pléistocène.)
B 5. Lacs Muskoka. (Excursion de fin de semaine permettant aux membres du Congrès de passer la journée du dimanche sur les lacs.)

SÉANCES SCIENTIFIQUES.

9h. du matin. Séance du Conseil. (Salle 16, édifice N° 23.)

10h. du matin. Séance générale. Sujet N° 7. "Les caractéristiques physiques des mers paléozoïques et les particularités de leur faune, considérées au point de vue de la portée du retour des mers dans l'établissement des systèmes géologiques. (Édifice N° 35.)

1. T. C. CHAMBERLIN. *The shelf-seas of the Paleozoic and their relations to diastrophism and time divisions.*
2. GUSTAV STEINMANN. *Die paläozoischen Meere in Südamerika.*
3. CHARLES SCHUCHERT. *The delimitation of the geologic periods, illustrated by the paleogeography of North America.*
4. F. FRECH. *The Palæozoics of the Bagdad railway.*
5. OLAF HOLTEDAHL. *On the Old Red Sandstone series of northwestern Spitzbergen.*

10.45h. du matin. Séance de la section spéciale. Tectonique. (Salle 8, édifice N° 23.)

1. TH. DAHLBLOM. *The angle of shear.*
2. E. HOWE. *Landslides and the sinking of ground above mines.*
3. D. McDONALD. *Excavation deformations.*
4. E. O. HOVEY. *Note on landslides.*

2h. du soir. Réunion de la Commission de la carte géologique d'Europe et du monde. (Salle 57. édifice N° 23.)

2.30h. du soir. Séance de la Section 1. Communications diverses. Géologie économique et chimique. (Salle 8. édifice No. 23.)

1. J. SAMOJLOFF. *Ergebnisse der geologischen Untersuchungen über die Phosphoritlagerstätten Russlands.*
2. CHARLES N. GOULD. *The occurrence of petroleum and natural gas in the Mid-continent field.*
3. J. DE SZÁDECZKY. *Natural gas in Transylvania.*
4. GEORGE F. KUNZ. *The geological occurrence of precious stones on the American continent.*
5. R. C. WALLACE. *A physico-chemical contribution to the study of dolomitization.*
6. M. F. CONNOR. *Some notes on rock analysis.*

2.30h. du soir. Séance de la Section 2. Sujet N° 7 (suite). (Salle 37, édifice N° 23.)

1. E. O. ULRICH. *The Ordovician-Silurian boundary.*
2. T. C. CHAMBERLIN and R. T. CHAMBERLIN. *Periodicity of Paleozoic orogenic movements.*

DIVERTISSEMENTS.

4h. du soir. M. et Mme. DAVID A. DUNLAP reçoivent les membres du Congrès et donnent en leur honneur un "garden-party." à leur villa de Rosedale, 93 Highlands Avenue.

9.30h. du matin et 2.30h. du soir. La ville de Toronto met des automobiles à la disposition des congressistes pour visiter les différents points intéressants de la ville.

Lundi 11 Août.

EXCURSIONS.

B 9. Orillia (principalement pléistocène).

SÉANCES SCIENTIFIQUES.

9h. du matin. Séance du Conseil. (Salle 16, édifice N° 23.)

10h. du matin. Séance générale. (Édifice N° 35.)

Propositions et rapports des Commissions internationales. Aprés réglement de ces questions, un séance spéciale a lieu dans le but de donner lecture des contributions.

1. BAILEY WILLIS, *The forty-first parallel survey of Argentina.*

2. L. MILCH, *Über die Plastizität des Steinsalzes und ihre Abhängigkeit von der Temperatur.*

3. P. QUENSEL. *On a new area of nepheline rocks in Sweden.*

2.30h. du soir. Séance de la Section 1. Sujet N° 3. L'influence de la profondeur sur la nature des gisements métallifères et contributions diverses. (Salle 8, édifice N° 23.)

1. J. F. KEMP, *The influence of depth on the character of metalliferous deposits.*

2. P. J. KRUSCH, *Primäre und sekundäre Erze unter besonderer Berücksichtigung der "Gel" und der Schwermetallreichen Erze.*

3. W. H. EMMONS, *The mineral composition of primary ore as a factor determining the vertical range of metals deposited by secondary processes.*

4. L. L. FERMOR, *On the formation in depth of oxidized ores and of secondary limestones.*

5. PAUL R. FANNING, *A contribution to the metallogeny of the Philippine Islands.*

6. MALCOLM MACLAREN, *The persistence of ore in depth.*

2.30h. du soir. Séance de la Section 2. Communications diverses.

1. PAUL BERTRAND, *Étude du stipe de l'Asteropteris noveboracensis.*

2. PIERRE PRUVOST, *La faune continentale du terrain houiller du nord de la France; son utilisation stratigraphique.*

3. E. T. MELLOR, *On the mode of deposition of the auriferous conglomerate of the Witwatersrand.*

4. A. E. DAY, *The age of the Nubian sandstone.*

5. CHARLES R. KEYES, *Certain features of eolic gradation.*

6. J. T. B. IVES, *Geological cartography.*

2h. du soir. Séance spéciale (suite). (Édifice N° 35.)

1. M. S. MASO and WARREN D. SMITH, *The relations of seismic disturbances in the Philippines to geologic structure.*

2. H. KEIDEL, *Über den Anteil der quartären Klimaschwankungen und der Gestaltung der Oberfläche des Gebirges im Trockengebiet der mittleren und nördlichen argentinischen Anden.*

3. W. PAULCKE, *Über tektonische experimente.*

4. W. E. PRATT, *Petroleum on Bondoc peninsula, Tayabas province, Philippines.*

5. SHIMMATSU ICHIKAWA, *Studies on the etched figures of Japanese quartz.*

6. S. A. PAPAVASILIOU, *L'émeri de Naxos.*

DIVERTISSEMENTS.

9.30h. du matin et 2.30h. du soir. La ville de Toronto met des automobiles à la disposition des congressistes pour visiter les différents points intéressants de la ville.

4-6h. du soir. Le Comité des dames de Toronto offre un thé dans le carré de l'université. (Édifice N° 23.)

5h. du soir. Dr. W. F. HUME, Directeur du Service géologique de l'Egypte, fait une conférence sur la nature du désert, des oasis, cataractes et montagnes sauvages de l'Egypte, accompagnée de projections lumineuses originales.

9h. du soir. Réception à l'hôtel de ville, par M. le Maire et le Conseil municipal de la ville de Toronto, en l'honneur du Congrès.

Mardi 12 Août.

EXCURSIONS.

B 1. Niagara.
B 2. Vallée du Don et Scarboro Heights. (Pléistocène.)
B 4. Rivière Crédit. (Silurien.)

Mercredi 13 Août.

EXCURSIONS.

B 7. Streetsville. (principalement paléontologique.)
B 8. Depôts d'argile près de Toronto. (industriels.)

SÉANCES SCIENTIFIQUES.

9h. du matin. Séance du Conseil. (Salle 16, édifice N° 23.)

10h. du matin. Séance générale. Sujet No. 4. L'origine et l'importance des sédiments précambriens. (Édifice N° 35.)

1. J. J. SEDERHOLM, *Different types of Pre-Cambrian unconformities.*

2. GRENVILLE A. J. COLE, *Illustrations of the formation of composite gneisses and amphibolites in northwest Ireland.*

3. John Horne, *The Pre-Cambrian sedimentaries between the Moine thrust and the eastern border of the Scottish Highlands.*

4. J. J. Sederholm, *On regional granitization (or anatexis).*

5. W. S. Bayley, *The Pre-Cambrian sedimentary rocks in the highlands of New Jersey.*

6. G. F. Matthew, *Cambrian and Pre-Cambrian in the maritime provinces of Canada.*

7. C. K. Leith, *The relations of the plane of unconformity at the base of the Cambrian to terrestrial deposition in late Pre-Cambrian time.*

10h. du matin. Section 3. Séance spéciale pour la lecture des articles non encore parvenus les jours précédents.

1. N. O. Holst, *Le commencement et la fin de la période glaciaire.*

2. W. von Lozinski, *Über erdgeschichtliche Kälteperioden.*

3. H. L. Fairchild, *New York state under the Labradorean ice-sheet.*

4. Warren Upham, *Fields of outflow of the North American ice-sheet.*

5. J. B. Tyrrell, *The Patrician glacier south of Hudson bay.*

2.30h. du soir. Séance générale. Sujet N° 5. Les subdivisions, la corrélation et la terminologie du précambrien.

1. A. Strahan, *The subdivisions and correlation of the Pre-Cambrian rocks of the British Isles.*

2. Andrew C. Lawson, *A standard scale for the Pre-Cambrian rocks of North America.*

3. J. J. Sederholm, *Some proposals concerning the terminology of the Pre-Cambrian.*

4. Sir T. H. Holland, *The Archæan and Purana groups of peninsular India.*

5. E. Vredenburg, *Note on the nomenclature and classification of the Pre-Cambrian systems of India.*

6. A. P. Coleman, *The Sudbury series and its bearing on Pre-Cambrian classification.*

7. C. K. Leith, *Pre-Cambrian correlation from a Lake Superior standpoint.*

8. W. H. Collins, *A classification of the Pre-Cambrian formations in the region east of Lake Superior.*

9. J. Deprat, *The geology of Indo-China and Honan.*

10. A. LACROIX. *Les roches alcalines de Madagascar comparées à celles des montagnes montérégiennes.*

11. A. LACROIX. *Les ressources minéralogiques de Madagascar.*

DIVERTISSEMENTS.

9h. du matin et 2.30h. du soir. La ville de Toronto met des automobiles à la disposition des congressistes pour visiter les différents points d'intérêt de la ville.

12.30h. du soir. Rassemblement des membres devant l'édifice N° 23 pour un groupe photographique.

4-6h. du soir. Le Comité des dames de Toronto offre un thé dans le carré de l'université. (Édifice N° 23.)

8.30h. du soir. Un banquet est offert, au nom du Canada, aux délégués et membres du Congrès, à l'Arsenal University Avenue.

Jeudi 14 Août.

EXCURSIONS.

Dans la soirée, départ des excursions, C 1 C 2, et C 6 de la gare Union, par le chemin de fer Canadien du Pacifique.

SÉANCES SCIENTIFIQUES.

9h. du matin. Séance du Conseil. (Salle 16, édifice N° 23.)

10h. du matin. Séance générale pour affaires diverses et clôture de la XIIe Session. (Édifice N° 35.)

DIVERTISSEMENTS.

4h. du soir. Assemblée spé[illegible] de l'Université de Toronto, au cours de laquelle de[illegible]ades honorifiques sont conférés à un certain nombre de membres du Congrès.

4.30h. du soir. Un "garden party" est donné, en l'honneur du Congrès, par les gouverneurs de l'université de Toronto, dans le carré de l'université. (Édifice N° 23.)

PROCÈS-VERBAUX

SÉANCES DU CONSEIL.

PREMIÈRE SÉANCE.

7 août.

La première séance du Conseil s'est ouverte à 10 heures du matin dans la Chambre du Sénat de l'Université. Les membres dont les noms suivent étaient présents:—

MM. F. D. Adams, Helge Bäckström, Luigi Baldacci, R. W. Brock, G. A. J. Cole, A. P. Coleman, T. C. Denis, D. B. Dowling, J. W. Evans, W. F. Ferrier, Fritz Frech, W. L. Goodwin, Arnold Hague, C. H. Hitchcock, W. F. Hume, J. P. Krusch, James McEvoy, W. G. Miller, G. A. F. Molengraaff, W. A. Parks, G. O. Smith, Gustav Steinmann, H. W. Stille, P. M. Termier, E. A. Tietze, Th. Tschernyschew, T. L. Walker, R. C. Wallace.

M. Adams, Président du Comité exécutif, souhaite en français la bienvenue aux membres. Après avoir demandé la permission d'employer la langue anglaise, il fait un bref résumé de l'objet de la séance et prie M. Brock, Secrétaire général, de lire les noms des délégués.

Sur motion de M. Smith appuyé par M. Termier, la liste est considérée comme lue.

M. le Secrétaire général, en l'absence de M. J. G. Anderson Secrétaire général du XIe Congrès, soumet à l'approbation du Conseil le projet suivant pour la composition du Bureau pour le XIIe Congrès:—

BUREAU.

Ancien président: Hofrat Emil Tietze.
Président: Dr. F. D. Adams.
Secrétaire général et Trésorier: R. W. Brock.
Vice-présidents:

Allemagne: Richard Beck, Alfred Bergeat, Fritz Frech, J. P. Krusch, Albrecht Penck, August Rothpletz, Gustav Steinman, H. W. Stille.
Argentine: Hans Keidel.
Australie: E. C. Playford.
Autriche-Hongrie: Lajos Lóczy de Lócz, Jules Szádeczky de Szádecsne, E. A. Tietze, R. Zuber.
Belgique: Armand Renier.
Bulgarie: Lazar Vankow.
Canada: Charles Camsell, D. B. Dowling, G. F. Matthew.

Chili: Ernst Maier.
Danemark: O. B. Bøggild, Victor Madsen.
Égypte: W. F. Hume.
Espagne: Agustin Marin y Bertran de Lis.
États-Unis d'Amérique: A. H. Brooks, J. C. Branner, T. C. Chamberlin, W. B. Clark, Whitman Cross, R. A. Daly, James Douglas, Arnold Hague, J. F. Kemp, A. C. Lawson, C. K. Leith, Waldemar Lindgren, Charles Schuchert, G. O. Smith, David White.
France: Charles Barrois, A. Bigot, Emmanuel de Margerie, P. M. Termier.
Grande-Bretagne: G. A. J. Cole, Alfred Harker, Sir T. H. Holland, John Horne, Sir Henry Miers, Aubrey Strahan.
Grèce: T. G. Skouphos.
Guinée-Britannique: J. B. Harrison.
Inde: L. L. Fermor.
Indo-Chine: J. Deprat.
Italie: Luigi Baldacci, Carlo de Stefani.
Japon: Kinosuke Inouye, Shukusuke Kôzu.
Madagascar: Alfred Lacroix.
Mexique: Teodoro Flores, Ezequiel Ordoñez.
Norvège: Olaf Holtedahl.
Pays-Bas: G. A. F. Molengraaff.
Empire Russe: (a) *Russie:* F. Loewinson-Lessing, Th. Tschernyschew, W. Vernadsky.
(b) *Finlande:* J. J. Sederholm.
Soudan: G. W. Grabham.
Suède: Helge Bäckström, H. S. A. Sjögren.
Terre-Neuve: J. P. Howley.
Tunisie: Paul Weiss.

La liste est approuvée.

Le Secrétaire général lit le programme du jour et propose la formation d'un comité pour établir des programmes quotidiens. Cette proposition est approuvée et le comité suivant est nommé: MM. Bäckström, Brock, Hume, Steinmann et Termier.

Le Secrétaire général lit la liste qui suit des présidents des diverses assemblées scientifiques:—

Sujet No. 1. Les ressources houillères mondiales: Th. Tschernyschew.

Sujet No. 2. Différenciation dans les magmas ignés: Helge Bäckström.

Sujet No. 3. L'influence de la profondeur sur la nature des gisements métallifères: G. O. Smith.

Sujet No. 4. L'origine et l'importance des sédiments précambriens. P. M. Termier.

Sujet No. 5 Les subdivisions, la corrélation et la terminologie du précambrien: Aubrey Strahan.

Sujet No. 6. Dans quelle mesure l'époque glaciaire a-t-elle été interrompue par des périodes interglaciaires? T. C. Chamberlin.

Sujet No. 7. Les caractéristiques physiques des mers paléozoiques et les particularités de leurs faunes considérées au point de vue de la portée du retour des mers, dans l'établissement des systèmes géologiques: Gustav Steinmann.

Assemblées diverses: Luigi Baldacci, Kinosuke Inouye, Waldemar Lindgren, Lajos Lóczy de Lócz Emmanuel de Margerie, Sir Henry Miers, J. J. Sederholm.

M. Smith demande que le nom de Waldemar Lindgren soit substitué au sien comme président de la section No. 3 et la liste, ainsi modifiée, est approuvée.

M. Tschernyschew pense que conformément à la tradition M. le Président du Congrès précédent aurait dû occuper la présidence jusqu'à la nomination formelle du nouveau président et qu'en l'absence de M. De Geer, la présidence revenait à M. Tietze, le seul ancien président présent.

Il est alors décidé que M. Tietze devra prendre officiellement la parole en qualité d'ancien président avant M. Bäckström, délégué suédois, à l'ouverture officielle.

Le Président présente la proposition de M. Samojloff tendant à l'adoption de l'investigation des ressources mondiales en acide phosphorique comme sujet principal pour le prochain Congrès, et la proposition de M. Bather demandant que la date du prochain Congrès soit avancée d'une année pour éviter tout conflit avec la date du Congrès Zoologique déjà fixée pour 1916.

La discussion de ces questions est remise à la séance suivante. La séance est levée.

SECONDE SÉANCE.

8 août.

La séance est ouverte à 9 heures du matin sous la présidence de M. F. D. Adams, le Secrétaire général, M. R. W. Brock, agissant comme Secrétaire.

Membres présents: MM. F. D. Adams, H. Bäckström, L. Baldacci, O. B. Bøggild, R. W. Brock, G. A. J. Cole, T. C. Denis, J. Deprat, J. W. Evans, E. R. Faribault, L. L. Fermor, G. W. Grabham, C. H. Hitchcock, J. Horne, W. F. Hume, K. Inouye, H. Keidel, J. P. Krusch, F. Loewinson-Lessing, E. Maier, G. O. Smith, G. Steinmann, A. Strahan, P. M. Termier, E. Tietze, Th. Tschernyschew et R. C. Wallace.

Le procès-verbal de la dernière séance est lu et adopté.

M. TSCHERNYSCHEW est ajouté à la Commission de la Publication d'un Lexique de Stratigraphie.

Le nom de L. E. GENTIL est ajouté à la liste du Bureau au nombre des Vice-présidents qui représentent la France.

La proposition de M. SAMOJLOFF, que les ressources mondiales en acide phosphorique constituent le sujet principal du prochain Congrès est alors mise à l'étude.

M. COLE est d'avis que le sujet pourrait être étendu de façon à inclure tous les minéraux utilisés en agriculture.

M. TERMIER fait remarquer combien il serait à désirer qu'une enquête soit faite au sujet du pétrole.

Le Président rappelle au Conseil que le pays qui recevra le prochain Congrès doit s'attendre à être consulté pour le choix du sujet de l'enquête. Si le prochain Congrès doit être tenu en Belgique, ce pays préfèrera probablement le sujet du cuivre à celui des phosphates.

M. KRUSCH signale la difficulté d'obtenir des compagnies des chiffres exacts relativement au cuivre, spécialement aux réserves cupriques. Il faudrait envoyer des géologues dans chaque cas, ce qui serait difficilement praticable et il pense que le pétrole serait un sujet préférable.

M. TSCHERNYSCHEW est en faveur du sujet des phosphates qui constituent pour l'agriculture un sujet de la plus haute importance. Le pétrole est un sujet complexe et difficile à traiter; dans le cas de la Russie, le sujet serait très compliqué.

Le Président réitère qu'il n'est que juste que le pays où le Congrès doit se tenir ait son mot à dire dans la question; la Suède était intéressée dans le fer et a préparé une monographie du fer; le Canada a de grands gisements de charbon et a préparé une monographie des ressources houillères. La question pourrait, à son avis, être remise à la prochaine séance.

M. COLE est d'avis que les phosphates doivent plaire à la Belgique qui est un pays agricole. Nous avons plus besoin de pain que d'automobiles. Dans le cas des phosphates, le travail ne serait pas être laissé aux soins des compagnies, mais, au contraire, confié aux géologues.

Comme l'heure est arrivée où les membres doivent se rendre aux comités, et qu'il reste encore quelques affaires courantes à expédier, le Président ajourne la discussion à une autre séance.

Le Secrétaire général soumet le programme du jour.

M. EVANS propose une autre conférence publique et conseille, puisque M. HUME possède une collection unique de plaques du désert, qu'on lui demande de fournir au public de Toronto une occasion de les voir.

La question est renvoyée au Secrétaire général avec la recommandation de trouver le temps propice pour une conférence de M. HUME, si c'est possible.

TROISIÈME SÉANCE.

9 août.

La séance est ouverte à 9 heures du matin sous la présidence de M. F. D. Adams, le Secrétaire général, M. R. W. Brock, agissant comme secrétaire.

Membres présents: MM. F. D. Adams, H. Backström, L. Baldacci, A. Bigot, R. W. Brock, W. B. Clark, G. A. J. Cole, A. P. Coleman, W. Cross, J. Depéret, C. de Stefani, J. A. Dresser, J. W. Evans, E. R. Faribault, W. F. Ferrier, T. Flores, F. Frech, L. E. Gentil, C. H. Hitchcock, W. F. Hume, K. Inouye, H. Keidel, J. F. Kemp, J. P. Kuesch, R. Lachmann, F. Loewinson-Lessing, E. Maier, G. A. F. Molengraaff, F. L. Ransome, A. Renier, A. Rothpletz, J. J. Sederholm, H. S. A. Sjögren, G. O. Smith, G. Steinmann, H. W. Stille, A. Strahan, J. de Szádeczky, P. Termier, E. Tietze, Th. Tschernyschew, J. B. Tyrrell, W. Vernadsky, R. C. Wallace.

Le procés verbal de la dernière séance est lu et adopté.

M. Steinmann présente le rapport de la Commission sur le Prix Spendiaroff proposant de donner le prix à Emile Argand pour son mémoire, *Les nappes de recouvrement des Alpes occidentales*, 1911, et soumettant les conditions suivantes pour le prochain prix:

"Le meilleur travail pétrographique apportant de nouvelles lumières sur les problèmes généraux de la science."

Le rapport est adopté.

Le Président demande au Conseil de constituer la commission chargée de décerner le prochain prix et les membres suivants sont appelés à faire partie de cette commission:—MM. Adams, Bäckström, Becke, Brögger, Cross, Harker, Karpinsky, Lacroix, Loewinson-Lessing, Milch, Molengraaff, Teall.

M. Renier remet au Conseil la cordiale invitation du Gouvernement de la Belgique et des géologues belges de tenir la treizième session du Congrès en Belgique et à l'appui de cette invitation, il fait ressortir les détails intéressants de géologie qu'on peut étudier en Belgique.

INVITATION.

Conformément aux instructions de Monsieur le Ministre de l'Industrie et du Travail et en confirmation de la correspondance échangée entre M. le Président Adams et M. le Directeur Général des Mines, Président de la Commission Géologique de Belgique, L. Dejardin, j'ai le grand honneur de vous apporter l'invitation formelle et officielle de tenir en Belgique la XIIIe Session du Congrès Géologique International. Cette invitation déjà présentée à deux reprises n'avait pu être prise en considération. Mais les géologues belges, assurés qu'ils sont de l'appui du Gouvernement, espèrent fermement que le Conseil voudra bien cette fois transmettre leur invitation à l'assemblée générale du Congrès en l'appuyant d'un avis favorable.

M. Smith propose, appuyé par M. Strahan, que l'invitation de la Belgique soit acceptée.

M. Keidel fit une invitation de M. Enrique Hermitte, Directeur Général des Mines, de la Géologie et de l'Hydrologie pour que la quatorzième réunion du Congrès soit tenu dans la République Argentine et indique les avantages scientifiques d'une réunion du Congrès en cet endroit, avec les intéressantes excursions que l'Argentine peut offrir aux géologues de toutes spécialités.

M. Mayer appuie l'invitation et annonce que le Gouvernement du Chili n'en avait pas eu connaissance, c'est pour cette raison seulement qu'il n'y avait pas participé. Il sait pertinemment que le Gouvernement du Chili ferait de son mieux pour induire le futur Congrès à ne pas s'arrêter seulement à la frontière Argentine-Chili mais à traverser le Chili, qui présente tant d'intérêt géologique et minéralogique. Il espère être en mesure de soumettre aux membres avant le Congrès belge une invitation officielle du gouvernement du Chili.

Le Président fait remarquer que le Conseil peut seulement recommander cette invitation aux membres du prochain Congrès.

M. Evans rappelle qu'à une session antérieure l'Espagne a adressé une invitation au Congrès et beaucoup de personnes trouveraient la géologie de l'Espagne très intéressante. Il désire savoir où en est l'invitation de l'Espagne.

M. Steinmann s'informe si, au cas où le Congrès se tiendrait en Argentine, il vaudrait mieux le tenir au printemps ou en automne.

M. Keidel répond qu'il vaudrait mieux le tenir en septembre.

Le Président présente une invitation de l'Exposition Panama-Pacifique de tenir une session à l'Exposition de San Francisco en 1915.

Sur motion de M. Smith appuyée par M. Cross l'invitation est déclinée.

Le Conseil met alors à l'étude la proposition de M. Bather qui se base sur le fait que les réunions du Congrès, en raison de la remise de la dernière session reculée d'une année, tombent maintenant tous les trois ans en même temps que celle du Congrès zoologique international et demande que la date des sessions soit changée à l'avenir pour ne pas venir en conflit avec les réunions zoologiques.

M. Frech fait remarquer l'inconvénient sérieux qui résulte de la réunion dans la même année des Congrès zoologique et géologique quand une question aussi importante que celle de la nomenclature doit être réglée. Les nomenclatures zoologique et paléontologique sont intimement liées et le travail des paléontologistes dépend de la nomenclature zoologique. Il pense en conséquence que la date du Congrès géologique international devrait être changée comme le propose M. Bather.

Dans la discussion générale qui a suivi, il a été parfaitement établi que le changement proposé a trait seulement au prochain Congrès afin d'éviter tout conflit avec le Congrès zoologique tant que l'importante question de nomenclature est en voie de règlement.

Il est alors proposé par M. Renier appuyé par M. Steinmann que le prochain Congrès soit tenu en 1917.

M. Baldacci désire qu'il soit bien convenu que cela ne constitue pas un précédent.

Le Président énonce que c'est l'année seulement du prochain Congrès qu'il s'agit de fixer.

La motion de M. Renier est adoptée.

M. le Secrétaire général soumet le programme du jour et la séance est levée.

QUATRIÈME SÉANCE.

11 août.

La séance est ouverte à 9 heures du matin sous la présidence de M. F. D. Adams; M. R. W. Brock, Secrétaire général, agissant comme secrétaire.

Membres présents: MM. F. D. Adams, H. Bäckström, L. Baldacci, A. E. Barlow, O. B. Bøggild, R. W. Brock, A. H. Brooks, G. A. J. Cole, A. P. Coleman, W. Cross, T. C. Denis, J. Déprat, C. de Stefani, J. W. Evans, E. R. Faribault, L. L. Fermor, T. Flores, E. Gentil, C. H. Hitchcock, Sir T. H. Holland, O. Holtedahl, J. Horne, W. F. Hume, K. Inouye, H. Keidel, J. F. Kemp, J. P. Krusch, A. Lacroix, F. Loewinson-Lessing, E. Maier, E. de Margerie, G. A. F. Molengraaff, Agustin Marin, A. Renier, A. Rothpletz, C. Schuchert, J. J. Sederholm, H. S. A. Sjögren, T. G. Skouphos, G. H. Smith, G. Steinmann, H. W. Stille, A. Strahan, J. de Szádeczky, P. M. Termier, E. Tietze, Th. Tschernyschew, J. B. Tyrrell, W. Vernadsky, T. L. Walker.

Le procès-verbal de la séance du 9 août est lu et adopté.

Le Président donne lecture d'une communication des représentants de l'Espagne renouvelant l'invitation présentée au Congrès de Stockholm pour que le quatorzième Congrès se tienne en Espagne.

INVITATION.

Monsieur le Président du XIIe Congrès Géologique International:

La représentation de l'Espagne au XIIe Congrès Géologique International a l'honneur de rappeler qu'au Congrès réuni à Stockholm notre pays fit l'invitation de célébrer à Madrid le Congrès suivant celui de Bruxelles.

La représentation de l'Espagne renouvelle son invitation et prie le Conseil de lui faire l'honneur de la prendre en considération dans ses délibérations.

Recevez, Monsieur le Président, nos salutations les plus distinguées.

(Signé) Agustin Marin.
E. Dupuy de Lôme.

Le président annonce que le délégué de la République Chinoise, M. Parkin Wong, est arrivé et propose qu'il soit ajouté au Bureau comme Vice-président pour la Chine. Approuvé.

M. de Margerie propose que la Commission de la Carte géologique soit accrue en y adjoignant des directeurs de services géologiques ou des géologues éminents en dehors de l'Europe, particulièrement ceux d'Asie et d'Afrique qui n'ont pas encore de representants dans la Commission. Une carte continentale comme celle de l'Amérique du Nord serait plus utile que des cartes en feuilles séparées. Il propose donc d'adjoindre à la Commission comme collaborateurs: J. Deprat, O. A. Derby, L. L. Fermor, L. E. Gentil, H. Hubert, W. F. Hume, K. Inouye, A. Lacroix, E. Maier, P. Marshall, E. T. Mellor, G. A. F. Molengraaff, G. Steinmann.

M. Steinmann propose d'ajouter le nom de M. de Margerie.

M. Evans propose d'ajouter le nom de M. A. E. Kitson, Directeur du Service géologique de la Côte d'Or.

M. Krusch appelle l'attention du Conseil sur la très ancienne organisation de la Commission de la Carte, qui date du premier Congrès et émet catégoriquement l'opinion que la Commission devrait faire elle-même les additions qu'elle juge opportunes, ainsi que cela s'est fait au Congrès de Stockholm. Au nom du président de la Commission, on avait invité les collaborateurs projetés à assister à la séance, ainsi que les autres personnes dont les avis auraient pu être utiles à la Commission. En raison des dépenses considérables qu'entraînerait la proposition de M. de Margerie et du temps déjà consacré par la Deutsche Geologische Reichsanstalt au projet agréé par le Congrès précédent, M. Krusch demande que la question ne soit pas décidée maintenant mais laissée en suspens jusqu' à la prochaine session du Congrès.

M. Horne conseille que la proposition de M. de Margerie soit renvoyée à la Commission pour sa séance ultérieure dans la journée.

En réponse à une demande de M. Cole, M. Krusch annonce que des avis de la séance ont été envoyés aux membres.

M. Tschernyschew qui vient d'arriver, émet, à la demande du Président, l'opinion que le Conseil n'a pas le droit de faire des additions au nombre des membres de la Commission à moins que la Commission ne le propose elle-même.

M. Krusch fait valoir des arguments adverses à l'accroissement de la Commission; le but de la proposition pourrait être atteint en invitant M. de Margerie et autres intéressés à assister à la séance et en les invitant à participer à la discussion.

Le sujet est donc renvoyé à la Commission et les intéressés sont invités à assister à la séance de la Commission à onze heures. M. Strahan représentera dans la commission M. Teall, comme fondé de pouvoir.

M. Krusch lit le rapport de la Commission sur une Enquête économique sur les Gisements de Fer du Monde.

M. Renier propose d'ajouter à la liste des collaborateurs le nom de M. Delmer de Belgique qui a fait une étude complète du sujet.

M. Coleman demande qui paiera les frais du travail. Il y aura, à son avis, beaucoup de travail de bureau et de fortes dépenses d'impression.

M. Krusch répond que chaque pays paiera les frais de son propre travail qui ne seront pas très élevé, car il s'agit seulement d'un remaniement des statistiques déjà obtenues.

Sur motion de M. Krusch appuyé par M. Sjögren, le rapport est adopté.

Le Secrétaire général lit le rapport du Comité exécutif du Douzième Congrès géologique international relatif à la proposition de M. Hobbs qui recommandait une Enquête internationale sur le sujet du Régime de Fracture de la Croûte terrestre.

"Le Comité exécutif regrette que, par suite des obligations qui lui ont incombé en vertu de la préparation de la série considérable d'excursions arrangées pour le Douzième Congrès international et de la publication de la Monographie des Ressources houillères mondiales, il lui a été impossible d'entreprendre la préparation additionelle d'une monographie relative aux fractures de la croûte terrestre recommandée par le Onzieme Congrès géologique international. Le Comité a donc l'honneur de demander respectueusement que cette tâche soit transmise au Comité exécutif du Treizième Congrès international."

La proposition de M. J. Samojloff, relative à une enquête sur les ressources mondiales en acide phosphorique qui avait été remise à plus tard lors de la séance du 8 août, afin de permettre au Conseil d'entendre de la part de M. Renier l'opinion de la Belgique, le pays qui sera chargé des enquêtes recommandées par le Congrès actuel, est mise à l'étude.

M. Renier explique que le Comité d'organisation belge conseille le cuivre comme sujet principal de discussion à la treizième session, pour deux raisons: après le fer, le cuivre est le métal qui présente pour les industries le plus d'intérêt, et d'autre part il of[illegible] un intérêt spécial au pays qui organise le Congrès; c'est pourquoi ce[illegible]e opinion du Comité mérite d'être prise en considération.

M. TERMIER propose comme sujet de discussion les ressources du monde en pétrole. Une monographie des différentes régions à pétrole serait, après le fer et la houille, de la plus haute importance.

M. COLE pense que la Belgique doit avoir le choix du sujet, fait ressortir les difficultés au point de vue géologique et pratique d'entreprendre une investigation sur les ressources de pétrole propre à présenter une valeur durable. Ce ne serait pas une investigation géologique dans le même sens que le fer et la houille; il est pour sa part en faveur du pétrole comme sujet et, comme il l'a dit à la séance du 8 août, le sujet des phosphates devrait être étendu de façon à comprendre les nitrates et les sources de potasse.

M. RENIER admet la difficulté de traiter la question du cuivre; mais elle n'est pas plus sérieuse que celle des dépôts de phosphates. [illegible] énonce l'opinion des géologues belges que l'enquête [illegible]rait avoir trait [illegible] cuivre en raison de son importance nationale pour leur région.

M. SMITH déclare que la question en jeu est celle des résultats à obtenir. Les États-Unis, il y a cinq ans, ont eu l'expérience que les meilleurs résultats avaient été atteints quant à la houille et au fer et ensuite viennent les roches phosphatiques qui, en qualité de dépôts stratifiés, pourraient être traités d'une façon assez analogue à la houille. Les résultats quant aux métaux ont été peu satisfaisants, car il s'agissait de quantités moindres, la production est à peu près proportionnelle à la masse; plus la masse est considérable, plus juste est l'évaluation. Le cuivre ne peut pas être traité avec autant de succès que le fer et la houille. L'expérience du passé montre qu'un recensement des ressources en phosphate pourrait s'exécuter facilement. Le pétrole viendrait ensuite en ligne d'importance.

M. KRUSCH, fait remarquer que les sels de potassium appartiennent en Allemagne au gouvernement qui ne permettra jamais de [illegible]re le calcul de ses ressources. Les ressources de cuivre sont difficiles à traiter et les calculs n'indiqueraient, dans les meilleurs conditions possibles, que l'approvisionnement pour les quatre ou cinq années à venir. A son avis, le pétrole est [illegible] meilleur sujet à choisir.

M. KEIDEL croit préférable, attendu que le prochain Congrès a lieu en Belgique, de laisser la Belgique faire son choix parmi les sujets désignés comme convenables par M. SMITH. Bien que la Belgique ne soit pas un pays où il existe beaucoup de bassins pétrolifères, l'Argentine offre du pétrole en grande quantité et, si la prochaine session du Congrès accepte définitivement l'invitation de l'Argentine, il se pourrait qu'une monographie des ressources en pétrole pût être celle qui conviendrait le mieux. Avec les phosphates on arrive à la fin du type actuel de monographies tendant à donner une évaluation des ressources; avec le pétrole et les monographies subséquentes il faudrait de préférence, faire surtout la description des différentes formes de gisements.

M. VERNADSKY insiste sur les résultats importants que pourrait donner au point de vue de la géologie et de la minéralogie une investigation des phosphates (page 154.)

M. MOLENGRAAFF exprime l'opinion que le secret serait beaucoup plus étroitement gardé au sujet des ressources du pétrole que d'aucunes autres, en raison de la concurrence très serrée entre les grandes compagnies.

M. TSCHERNYSCHEW juge que le prix des monographies est trop élevé pour les géologues. Chaque pays devrait être appelé à payer sa part du travail ou s'engager à acheter un nombre spécifié d'exemplaires de la monographie complète, de façon que le rapport puisse être publié in extenso. Il regrette que le rapport de la Russie auquel avaient été consacrées trois années de travail n'ait pas été publié intégralement. Cela n'est pas satisfaisant et si cette pratique devait être suivie à l'avenir, la Russie refuserait de collaborer aux monographies futures.

La suite de la discussion a été remise à la séance suivante.
Les détails du programme de la journée sont annoncés.
La séance est levée.

CINQUIÈME SÉANCE.

13 août.

La séance est ouverte à 9 heures du matin sous la présidence de M. F. D. ADAMS. M. R. W. BROCK, Secrétaire général, agissant comme secrétaire.

Membres présents: MM. F. D. ADAMS, H. BÄCKSTRÖM, L. BALDACCI, A. BIGOT, O. B. BÖGGILD, R. W. BROCK, G. A. J. COLE, A. P. COLEMAN, W. CROSS, J. DEPRAT, C. DE STEFANI, J. W. EVANS, E. R. FARIBAULT, L. L. FERMOR, T. FLORES, F. FRECH, L. E. GENTIL, Sir T. H. HOLLAND, W. F. HUME, K. INOUYE, H. KEIDEL, J. F. KEMP, J. P. KRUSCH, A. LACROIX, E. MAIER, E. DE MARGERIE, G. A. F. MOLENGRAAFF, A. MARIN, A. RENIER, A. ROTHPLETZ, J. J. SEDERHOLM, T. SKOUPHOS, G. O. SMITH, G. STEINMANN, H. W. STILLE, J. DE SZÁDECZKY, P. M. TERMIER, E. TIETZE, TH. TSCHERNYSCHEW, J. B. TYRRELL, W. VERNADSKY.

Le procès-verbal de la séance du 11 août est lu et adopté.

A la demande du Président la discussion de la proposition de M. SAMOILOFF relative à une enquête sur les ressources en acide phosphorique, laissée en suspens à l'assemblée du 11 août, est reprise.

M. RENIER parlant en son nom et en celui de ses collègues belges dit qu'il y a trois propositions dont il faut s'occuper simultanément: les phosphates, le pétrole, et la proposition du gouvernement belge qui, à son avis mérite d'être prise la première en considération et présente pour les géologues belges la plus haute importance—les ressources mondiales en cuivre.

On s'est opposé à la proposition belge en raison des difficultés que soulève l'évaluation des ressources mondiales en cuivre. Ces difficultés, à son avis, se retrouvent au même degré dans tous les autres sujets présentés ou proposés. Il est prêt à accepter toutes les propositions raisonnables. La Belgique préfère le cuivre mais se met à la disposition du Congrès.

Sur motion de M. Krusch, appuyé par M. Hume, il est résolu que le Conseil ne devrait pas décider du sujet mais laisser ce soin au Comité d'organisation du prochain Congrès.

M. Renier remercie le Conseil de cette preuve de confiance. Les géologues belges feront de leur mieux pour mener le travail à bonne fin, avec l'assistance des membres du Congrès; il fait appel spécialement à la coopération de M. Smith dont l'expérience est excessivement précieuse.

M. Frech présente les rapports de la Commission de la Palæontologia Universalis (page 132) et de la Commission de la Publication d'un Lexique de Stratigraphie (page 132). Il explique que ces Commissions ont été obligées d'attendre la décision du Congrès zoologique au sujet des règles de nomenclature, parceque urs travaux reposaient sur cette décision. La publication de ces travaux nécessite des fonds. Son Excellence, le professeur Tschernyschew a généreusement promis de l'assistance de la part de l'Académie des Sciences de St.-Pétersbourg, et M. Frech demande que les autres corps scientifiques prêtent le même concours.

M. Renier signale à l'attention le Congrès botanique de Bruxelles. La Commission aurait là un précieux collaborateur dans la personne du docteur Youngman, paléobotaniste.

M. Frech propose de changer le nom de Palæontologia à celui de Palæozoologia, attendu que la botanique constitue un sujet distinct. Il propose, appuyé par M. Krusch, que les rapports soient approuvés et soumis à l'assemblée générale. Les rapports sont approuvés.

M. Krusch lit les rapports de la Commission de la Carte géologique internationale et la nouvelle Carte mondiale (page 141).

M. de Margerie propose d'ajouter à la Commission le nom de M. Fischer comme représentant de l'Algérie; M. Evans propose le nom de M. Kitson pour la Côte d'Or; et M. de Stefani, le nom du docteur Parona pour l'Afrique Italienne.

M. Hume est d'avis que la Commission devrait s'adresser officiellement aux gouvernements qui n'ont pas encore souscrit, plutôt que de confier cette tâche à ses membres, parceque la demande serait ainsi plus efficace. Il desire connaître les noms des gouvernements qui ne se sont pas encore inscrits sur la liste des souscripteurs.

M. Krusch annonce que la Commission s'est adressée directement aux gouvernements. Il ne peut pas dire quels gouvernements ont répondu, parce qu'il a été absent depuis deux mois et que des réponses ont pu parvenir dans l'intervalle.

M. Frech suggère que la Commission obtienne le droit de solliciter la coopération d'autres pays.

Sur motion de M. Krusch, appuyé p M. Frech, le rapport de la Commission est approuvé et devra être soum... à 'assemblée générale.

Sur la demande de M. REID, agissant au nom de M. le docteur RABOT, président de la Commission, M. DE MARGERIE, présente le rapport de la Commission internationale des Glaciers (page 144). Comme elle est d'un caractère général et de teneur en grande partie historique, il suggère que ce rapport soit approuvé sans être lu et qu'il soit présenté dans cet état à l'assemblée générale où se fera la lecture. Cette proposition est approuvée.

Le programme du jour est annoncé.

M. HUME est nommé président de la séance spéciale de la Section 3 qui se réunit à 10 heures.

La séance est levée.

SIXIÈME SÉANCE.

14 août.

La séance est ouverte à 9.10 heures du matin sous la présidence de M. F. D. ADAMS, le Secrétaire général, M. R. W. BROCK, agissant comme secrétaire.

Membres présents: MM. F. D. ADAMS, H. BÄCKSTRÖM, A BIGOT, O. B. BÖGGILD, R. W. BROCK, A. H. BROOKS, J. M. CLARKE, G. A. J. COLE, J. DEPRAT, C. DE STEFANI, J. W. EVANS, E. R. FARIBAULT, W. F. FERRIER, T. FLORES, G. W. GRABHAM, Sir T. H. HOLLAND, W. F. HUME, K. INOUYE, H. KEIDEL, J. P. KRUSCH, A. C. LAWSON, G. G. S. LINDSEY, F. LOEWINSON-LESSING, E. MAIER, E. DE MARGERIE, W. G. MILLER, A. MARIN, A. RENIER, J. J. SEDERHOLM, T. G. SKOUPHOS, G. O. SMITH, A. STRAHAN, G. STEINMANN, P. M. TERMIER, TH. TSCHERNYSCHEW, W. VERNADSKY, T. L. WALKER, R. C. WALLACE, D. WHITE.

Le procès-verbal de l'assemblée du 13 août est lu et adopté.

M. DE STEFANI propose d'envoyer un télégramme de félicitation au docteur CAPELLINI, un des plus anciens et des plus distingués géologues vivants, qui vient d'atteindre sa quatre-vingt-quatrième année.

La proposition est approuvée et le secrétaire est autorisé à envoyer le télégramme.

Le Président lit des lettres de MM. BECKER et HALET de la Commission du Degré géothermique (page 149).

M. STRAHAN explique qu'il a été prié par M. BECKER, obligé de s'absenter, de s'occuper de ce Comité, mais qu'il lui a été impossible de réunir un nombre de membres suffisant pour tenir une séance. Il considère les recommandations que contient la lettre de M. HALET comme très utiles; si l'on veut que la Commission réussisse à accomplir quelque chose il faut absolument poser des questions bien nettes et ne pas se contenter d'envoyer aux collaborateurs des lettres leur demandant des renseignements généraux sur le sujet. M. HALET conseille qu'une circulaire imprimée soit envoyée pour définir exactement la nature des renseignements désirés et cette proposition est certainement bonne. Si la Commission doit entreprendre une investigation sur la radioactivité comme le propose M. BECKER il serait nécessaire d'ajouter à la liste des noms de spécialistes dans cette partie. Il recommande que la proposition de M. HALET soit adoptée mais que la portée de l'investigation ne soit pas élargie actuellement au point de comprendre la radioactivité.

M. VERNADSKY pense que l'étude de la radioactivité est très importante et qu'on devrait s'en occuper.

Sur motion de M. BÄCKSTRÖM la recommandation de M. HALET et la proposition de M. BECKER relatives à l'adjonction au travail de la Commission d'une enquête sur la radioactivité soit laissée à la décision de la Commission elle-même et le rapport est approuvé.

Le Président lit ensuite la proposition de M. SEDERHOLM (page 157) relative à la coopération des gouvernements qui ont des étendues contiguës de roches précambriennes dans la corrélation de ces formations.

M. COLE approuve la proposition qu'il juge très avantageuse. Il croit que l'idée a déjà été mise en pratique entre le Canada et les États-Unis.

M. SMITH dit qu'une entente de ce genre a été effectuée; mais il n'est pas prêt à affirmer qu'elle a été menée à bonne fin.

M. COLE pense que cette proposition devrait indiquer la ligne de conduite à suivre.

M. LAWSON propose que la résolution soit modifiée de façon à impliquer une demande aux chefs de services géologiques d'agir en la matière

M. KRUSCH conseille que la proposition de M. SEDERHOLM soit changée en substituant le terme de services géologiques à celui de gouvernements.

La proposition de M. SEDERHOLM, avec substitution des mots "services géologiques" à "gouvernements" est alors approuvée dans cet état pour être soumise à l'assemblée générale.

Le Secrétaire général propose la nomination d'une commission comprenant le Secrétaire général du Comité exécutif du prochain Congrès et deux anciens Secrétaires généraux choisis par ce dernier pour décider de la forme de la monographie que le Congrès doit préparer; du nombre de pages attribuées à chaque pays et des dates auxquelles les manuscrits doivent être remis; cette Commission ayant aussi le pouvoir de faire des règlements relatifs à la livraison par les collaborateurs des illustrations et des cartes sous une forme qui convienne aux procédés de reproduction (page 157).

M. BROCK explique que, dans le cas de la Monographie des Ressources Houillères, avant d'envoyer des demandes de collaboration un estimé approximatif des réserves probables de chaque pays avait d'abord été fait et sur cette base, une répartition de l'espace disponible pour les divers rapports avait été exécutée, en tenant compte des additions qu'il faudrait faire dans les cas où les matériaux seraient particulièrement nouveaux et inédits. On a obtenu ainsi un nombre approximatif de pages pour chaque pays, de façon à composer une monographie bien équilibrée en deux volumes. On a ensuite demandé aux divers pays de préparer leur rapports conformément à l'espace qu'il leur était attribué.

Les rapports ont été demandés le 1er janvier 1912, afin de laisser le temps d'éditer, de disposer et de résumer avec soin. En décembre 1912, la Commission n'avait pas encore reçu la moitié des manuscrits et afin de pouvoir être sûr que le rapport serait publié, il a fallu passer un contrat pour le travail sans même savoir ce qu'il contiendrait.

Plus tard, comme les rapports soumis étaient généralement plus longs que l'on avait demandé et comme on hésitait à les condenser, le contrat a été modifié de façon à s'appliquer à trois volumes, ce qui naturellement augmentait le prix. Au milieu d'avril, après l'expiration du délai fixé par le contrat pour la livraison des derniers manuscrits, quelques rapports n'étaient pas encore parvenus et il a fallu câbler plusieurs fois avant de les avoir tous; nous étions arrivés presqu'au milieu de mai avant d'av[illegible]r reçu le rapport complet d'un pays en particulier. Bien qu'on n'eût [illegible]s fait de démarche en vue d'un espace plus considérable que celui qui était attribué, le rapport qui nous était soumis était assez long pour occuper au moins un volume tout entier et il comprenait aussi soixante ou soixante-dix cartes, dont la plupart devaient être redessinées pour pouvoir être reproduites. Malgré tout cela on a donné à ce rapport plus d'espace qu'on n'en avait accordé à tous les autres pays, sauf un seul. Pour arriver à cela il a fallu sacrifier dans une grande mesure les résumés de chapitres, et les auteurs n'ont pas eu assez de temps pour traiter ce sujet comme il convenait. C'était un sacrifice mais la monographie a été publiée à temps.

Ceux qui ont la direction d'une enquête de ce genre n'aiment pas à rogner les rapports; ils ne peuvent pas le faire aussi bien que le ferait le pays lui-même, mais le prix de la monographie doit rester dans les bornes et la monographie doit être prête à temps pour le Congrès. Il n'est pas équitable de leur demander d'endosser la responsabilité de mettre de côté des rapports et cependant, cela peut être nécessaire dans l'intérêt du Congrès et du reste du monde. M. Brock pense que la responsabilité devrait incomber à une petite commission internationale et non au pays qui dirige l'enquête.

M. Renier approuve cordialement la proposition. Il juge la question de la plus haute importance; pour arriver à un résultat satisfaisant il importe de profiter de l'expérience du passé et d'établir des règles fixes.

Le docteur Evans propose que le Comité détermine aussi si quelque groupement en particulier remplit les conditions requises.

La proposition est adoptée pour être soumise à l'assemblée générale.

M. Brock propose qu'un petit comité international, composé de pas plus de huit personnes ayant eu une expérience réelle dans les comités exécutifs des diverses sessions du Congrès, soit nommé et chargé d'étudier la préparation d'une constitution permanente et de soumettre, si c'est possible, une proposition à ce sujet à la session prochaine du Congrès (page 157). A l'appui de cette proposition, M. Brock fait remarquer que le Congrès géologique international existe depuis 1878 et que depuis cette époque son caractère s'est grandement modifié. Il n'a pas de constitution, ni de règles de direction permanentes. Il n'a pas d'inscription stable. Les membres y adhèrent chacun pour une seule session.

L'utilité générale du Congrès a été pleinement démontrée et il est temps maintenant d'étudier une constitution permanente.

M. Renier appuie la proposition. Bien que les Congrès précédents se soient réunis jusqu'à présent sans accident imprévu, il pense que, dans le cours des événements, une nation pourrait peut-être se trouver dans l'impossibilité de préparer sa session. Il espère que la proposition de M. Brock sera adoptée et que le comité belge jouira pour la treizième session de l'assistance de ce Comité.

M. Steinmann juge qu'une commission permanente de cette nature est une nécessité et qu'il serait aussi nécessaire de mettre quelques moyens à sa disposition, ce qui pourrait se faire facilement en relevant simplement l'honoraire usuel de cinq dollars.

M. Renier conseille que les deux propositions restent séparées et qu'on vote d'abord sur le principe posé dans la proposition de M. Brock. Avant d'étudier la proposition de M. Steinmann il préférerait attendre une ou deux sessions pour que l'on puisse acquérir quelqu'idée du champ d'action d'un comité de ce genre.

Après quelques idées émises par MM. Steinmann, Lawson et Brock, relativement à la souscription annuelle, M. Renier insiste encore sur la nécessité d'attendre que l'on ait recueilli quelqu' expérience au sujet des besoins financiers.

M. Krusch pense que les attributions d'une commission de ce genre devrait être strictement limitées. Cette question devrait être étudiée au cours des quatre années á venir et au prochain Congrès en Belgique, après expérience acquise, on pourrait voir comment il fonctionnera.

M. Bäckström fait remarquer que le comité proposé est simplement destiné à étudier ce qu'il serait à propos de faire et à soumettre ses idées au prochain Congrès.

M. Lawson conseille que l'on demande au comité nommé de faire ses propositions et de les soumettre à la prochaine session.

M. Renier pense que tout devrait être prêt pour le quatorzième Congrès afin d'éviter autant que possible toute cause de froissement.

La proposition de M. Brock est alors adoptée et la nomination du comité est laissée aux mains du Président du Congrès actuel, le douzième Congrès (page 158).

M. Walker propose que des télégrammes de félicitations soient envoyés à un certain nombre de géologues âgés et distingués qui n'ont pas pu être présents.

Après quelque discussion on émet l'idée d'ajouter le nom du docteur Edouard Suess à celui de M. Capellini à qui le Secrétaire général a déjà été autorisé d'envoyer un télegramme de ce genre.

La séance est levée.

SÉANCES GÉNÉRALES.

SÉANCE D'OUVERTURE.

7 août.

Le Congrès est ouvert à midi, dans la salle des facultés de l'Université de Toronto, en présence d'une brillante assemblée de représentants du Gouvernement canadien, des provinces, de la ville de Toronto et de groupes scientifiques, de même que d'un grand nombre de membres et délégués éminents.

Un peu avant midi, le Président et les membres du Comité exécutif, accompagnés des représentants des gouvernements fédéral et provinciaux, et les diverses sociétés et établissements scientifiques se réunissent dans l'antichambre pour escorter jusqu'à l'estrade son Excellence Sir Charles Fitzpatrick, P.C., G.C.M.G., administrateur en l'absence de Son Altesse royale le duc de Connaught, gouverneur général du Canada, et celui-ci ouvre la séance.

Son Excellence, avant de souhaiter la bienvenue aux congressistes, donne lecture du cablogramme suivant, reçu de Son Altesse royale:

> "Please convey to members of Geological Congress warmest wishes for success of Congress. Regret that, owing to my enforced absence from Canada, I am unable to open it personally."

Il est également porteur d'un message de la part du Premier Ministre du Canada, le priant tout particulièrement d'exprimer son profond regret d'être retenu par des affaires publiques de haute importance. Et Son Excellence prononce l'allocution suivante:

Ladies and gentlemen:

When I was first charged with the very pleasant duty of coming here to bid you welcome on behalf of the people and the government of Canada, my natural impulse was to address you in the language which I had been taught at my mother's knee. Having, however, this morning discovered by the aid of one of the many well-informed newspapers that are published in Toronto, that there are no less than twenty-three different languages spoken by the members of this Congress, I came to the conclusion that it was necessary that I should reconstruct myself and, instead of speaking to you in English, address you in the official language of the Congress, le beau parler de France.

There is this additional reason why I should speak in French. French is one of the official languages, as you know, of this country. It is also the language that was spoken by those hardy pioneers, those priests, warriors and traders who first sailed up the St. Lawrence, explored the Great Lakes, discovered the Mississippi and laid so broad and deep the foundations of this Canadian nation. And, may I add, it is a great tribute to the wisdom and to the liberality of our rule that it is made possible for so many thousands of Canadian subjects to do grace to the name of our Sovereign in the language that was spoken by CARTIER and by CHAMPLAIN. Vous me croirez sans peine quand je vous dirai que l'honneur et la satisfaction que j'éprouve à vous souhaiter la plus cordiale bienvenue sur notre terre canadienne me fait oublier la témérité qu'il y a pour un profane de s'associer, même sous forme de respectueux hommage, à des travaux scientifiques d'une nature si élevée, que seuls d'éminents spécialistes peuvent les aborder.

Pourtant ce bonheur est troublé par le regret que nous éprouvons tous bien vivement, de ne pas voir en cette place Son Altesse royale le DUC DE CONNAUGHT, gouverneur général du Canada. Vous auriez admiré dans sa présence cette suprême dignité, cette sagacité, cette grâce exquise et vraiment enveloppante dont il laisse l'empreinte dans ses moindres démarches.

C'est en son auguste nom et au nom du Gouvernement de la Puissance du Canada que je vous remercie de l'honneur insigne que vous faites à l'Université de Toronto d'y tenir votre douzième Congrès géologique international. Le mouvement scientifique qui se poursuit avec une intensité remarquable dans cette ville, trouvera dans votre présence de nouveaux et très précieux encouragements, et la soutiendra dans sa lutte de généreuse émulation avec les autres universités canadiennes et américaines.

Veuillez être vous-mêmes, messieurs les délégués, les interprètes de nôtre plus sincère reconnaissance auprès des nombreuses puissances et institutions scientifiques que vous représentez ici officiellement.

L'honneur que vous nous faites est d'autant plus apprécié que sur les onze sessions précédentes deux seules furent tenues en Amérique: la première à Washington en 1891, la seconde à Mexico en 1906. Il est vrai qu'elles eurent dans la suite logique de vos travaux une importance capitale. Le premier constata avec éclat et non sans admiration les richesses géologiques du sol américain et fit ainsi la connexion des deux mondes; le second traça en lignes claires et vigoureuses l'esquisse de la carte géologique de ce continent.

La session que vous inaugurez aujourd'hui avec de si fermes espérances va compléter ces travaux préliminaires en établissant la monographie des gisements carbonifères du monde. Elle sera en même temps un chapitre additionnel à l'œuvre du Congrès de Stockholm si brillamment inauguré par Sa Majesté le roi de Suède. Vous y avez établi la monographie des minerais de fer. Et comment ne pas vous féliciter d'y avoir trouvé l'active et intelligente collaboration de Son Altesse royale le prince héritier de Suède.

Vos travaux se poursuivent avec une telle ardeur et de si rigoureuses méthodes que déjà la magnifique carte géologique de l'Europe est sur le point d'être achevée et que je ne trouve pas téméraire de donner aux plus jeunes d'entre vous l'espoir de voir terminée celle du monde entier.

Il me semble qu'une principale cause de vos succès est précisément l'institution de ces Congrès internationaux dans lesquels des savants d'une réputation mondiale se rencontrent pour mettre en commun et ériger en synthèse les trésors scientifiques acquis par les efforts combinés des pouvoirs publics et des entreprises privées.

Comment, par exemple, ne pas reconnaître les avantages qu'ont nos géologues canadiens de pouvoir confronter leurs découvertes avec celles que vous faites dans vos pays respectifs. Et vous, messieurs, ne vous est-il pas souverainement profitable d'avoir l'occasion de fortifier vos hypothèses, vos critiques, vos résultats positifs et même vos procédés par une expérience plus universelle et s'étendant sur des pays neufs comme le nôtre. Je ne parle pas des relations qui s'établissent entre vous et nous, permettant de perpétuer les fruits de ces concours.

Vous avez trouvé au Canada un champ d'observation presque illimité. Toutes les formations depuis les plus anciennes jusqu'aux plus récentes sont représentées avec une abondance et une continuité qui font l'admiration des connaisseurs.

Ici, point de miniatures géologiques, ce sont des tableaux à proportions gigantesques.

Ainsi la chaîne des Cordillères canadiennes s'étend sur une longueur de 1300 milles et une largeur de 400; la région du plateau Laurentien présente une superficie de 2,000,000 milles carrés, cela fait plus de la moitié du Canada.

Dans ces immensités on a fait des travaux de reconnaissances; mais, il faut bien l'avouer, c'est là que l'histoire géologique aura à combler les plus fortes lacunes, même après les essais si hardiment amorcés par Sir WILLIAM LOGAN dont vous avez honoré la mémoire en assistant à l'inauguration d'une plaque commémorative.

Qu'on ne soit cependant pas trop dur à nous blâmer de ces retards qui contrastent avec les progrès européens; qu'on se souvienne de ces immensités elles-mêmes, encore pratiquement inexplorées dans certaines parties. Et puis, nous ne sommes nés que d'hier et avons eu à pourvoir aux premières nécessités de la vie en développant les richesses agricoles.

Les éminents géologues et ingénieurs des mines qui nous honorent de leur présence ont pourtant pu remarquer que le Canada, quoique tout nouveau venu, fait déjà bonne figure parmi les contrées minières. Dès leur arrivée, ils ont eu l'occasion de voir les gisements carbonifères et aurifères de la Nouvelle-Écosse; les minerais de fer, ainsi que les gisements d'huile et de gaz du Nouveau-Brunswick; les mines de chrome et d'amiante de Québec; de corindon, de fer, de nickel de Sudbury; les importantes mines d'argent de Cobalt et les mines d'or de Porcupine dans l'Ontario.

Pendant les loisirs que leur laisseront les séances du Congrès, ils pourront visiter la grande cataracte de Niagara et étudier les dépôts glaciaires et post-glaciaires du sud-ouest de l'Ontario. Ceux qui après la clôture du Congrès se dirigeront vers l'ouest auront le loisir d'examiner les grands gisements carbonifères de la Saskatchewan, de l'Alberta et de la Colombie Britannique, ainsi que les dépôts de cuivre de Phœnix et de cuivre aurifère de Rossland et du sud de la Colombie Britannique.

Je m'excuse, messieurs, de retenir si longtemps votre attention. Si, pourtant, il m'était permis d'ajouter à ma respectueuse sympathie un vœu pour votre avenir, je n'aurais qu'à vous souhaiter de rester fidèles à votre devise: "*Mente et malleo.*"

Pour fixer la valeur d'une statue sortie d'un des rares ateliers où le génie a pris demeure, nous ne considérons pas seulement les coups de ciseau qui l'ont taillée et polie, nous voulons y trouver la marque de l'esprit qui l'a conçue et l'a vivifiée dans toutes ses parties.

Sans doute, le passage du marteau révèle l'habileté du métier, mais il se tait sur la sublimité de la pensée qui, pénétrant dans le marbre, lui a donné la vie, une vie si supérieure à celle qui nous entoure que nous parlons de prodiges, de miracles et que nous appelons l'artiste un véritable créateur.

C'est l'esprit seul qui retrouve et reconnaît l'esprit. Vous êtes tellement pénétrés de la nécessité de cette règle éternelle de l'art que vous l'avez mise comme une enseigne, bien en évidence, au-devant de vos travaux d'art géologique.

L'instrument qui vous conduit au-devant des plus graves problèmes que recèle la terre n'est jamais seul à fonctionner. S'il fonctionnait seul, il n'aurait que la valeur de ce coup de marteau qui échappe de la main d'un [illegible] et qui au hasard défigure la statue ou achève un de ses traits. C'est votre esprit, c'est votre génie qui guide la pioche et lui permet de révéler un ordre, une harmonie géologique que d'autres siècles n'ont même pas soupçonnés. Vos travaux d'approche, vos anxieux sondages vous mettent en face de traces, de signes plus ou moins évidents d'un plan primitif que vous cherchez. Ce plan n'est autre chose que la Raison qui a présidé à la construction du monde. Votre raison s'accroche avec hardiesse à cette Raison et la force à se révéler, quitte à soumettre les résultats obtenus à l'épreuve du futur observateur.

C'est la voie que nous a montrée le grand CLAUDE BERNARD:

> "Le fait suggère l'idée, l'idée dirige l'expérience, l'expérience juge l'idée."

Ce même esprit, se souvenant des lourds travaux de l'instrument et de ses propres hésitations, vous garantit contre toute présomption. Il vous dit que vos lois ne sont que des "approximations successives du système de la nature." Ce sentiment de prudence et de réserve ne vous décourage cependant pas, parce que vous avez la conviction que ces approximations "traduisent dans le langage de l'homme les pensées du Créateur" et vous conduisent peu à peu vers le dernier mot de la science humaine, la Vérité.

Je termine en vous souhaitant la plus cordiale des bienvenues sur cette terre bénie, la patrie canadienne.

L'honorable W. H. Hearst, Ministre des Terres, Forêts et Mines de l'Ontario, prend ensuite la parole:

Ladies and gentlemen,

On behalf of the government and the people of the Province of Ontario permit me to extend to you our heartiest welcome and warmest greetings. At the present time we hear much about peace celebrations and much concerning means for the preservation of the peace of the world, and these are very good; but to my mind there is nothing, perhaps, that makes so much for the march of progress, for peace and for the betterment of man as meetings such as this, where we make acquaintances and form friendships that will last as long as life itself, and learn by mingling with our fellow men from the different nations and countries of the world that a man is a man, no matter what his nationality, no matter what his creed may be, and no matter to what flag he may own allegiance.

Many of you are making your first visit to the Province of Ontario and we trust that you will find here matters worthy of consideration and study. We are somewhat proud of the progress that we have already made in mining; we are proud of our position as a silver-producing and nickel-producing country. Within the last ten years the mineral production has increased by 100 per cent. And yet, in addition to that, we have millions upon millions of acres that have never been mapped by geologists, millions of acres never even visited by the explorer or prospector. We feel these are matters that will be of interest to you and we trust that your visit among us will be one of profit and pleasure.

I trust that this Congress may prove to be a pleasant and a very profitable gathering. And in conclusion, let me say that the province is yours, its freedom, its citizenship; and the government of the province and its people are yours to command."

M. le Commissaire Church parlant au nom de M. le maire Hocken de Toronto s'exprime ainsi:

Ladies and gentlemen;

I have very much pleasure on behalf of the Mayor and Corporation of the City of Toronto to give you a hearty welcome to our city.

The City of Toronto and the Province of Ontario are honoured in having so many great men of science meet here. You have honoured the University of Toronto, of which our citizens and our province are so proud, by holding your triennial Congress in our city.

We give you a hearty welcome to the city, we give you the freedom of the city, and hope that, when you go back to your own homes, you will carry pleasing memories of pleasant days spent in the University of Toronto and in the City of Toronto.

M. R. A. FALCONER, président de l'Université de Toronto dit:

Your Excellency, Mr. President, ladies and gentlemen:

You have had a welcome extended to you by the Administrator of the Dominion on behalf of the Government of Canada. You have had a welcome, also, given to you on behalf of the province by the Honourable Mr. HEARST, and the city has just spoken through Mr. Controller CHURCH, and has extended to you the opportunities and the privileges of this beautiful town. This is the tribute that has been paid to your science by the world without. Now, I think it is in place that tribute should be given to you by the world within, if I may be allowed that expression. Your science is indeed one of ancient prestige. Thousands of years ago the old Hebrew prophet spoke in praise of what was the science of his day, when he sang of the discoveries of wisdom and of the results of wisdom in these words: "There is a mine for silver and a place for gold, where they refine it. Iron is taken out of the earth and brass is molten out of the stone." An ancient and honourable science, then, yours is, Mr. Chairman.

You come now to the universities, and at this time I speak not merely in the name of the University of Toronto, but of all the universities of the Dominion of Canada. You come to the heart and home where science is nurtured in her infancy, where she is strengthened in her maturity and where she is comforted in the persons of her sons, when they return from their occupations to refresh their minds in the strenuous game of this zealous pursuit of truth, that goes on so often unheeded by the world outside. You come from many nations, as has already been stated. Probably every country of the civilized world is here represented. You have brought with you the richest equipment that the universities of your own lands could give you. You have brought with you the experience of many years, and you have brought with you the seeing eye, as His Excellency intimated in the quotation of his speech a few moments ago, the seeing eye that is able to see and criticise your experience.

In your movements to and fro through this Dominion in company with our Canadian geologists you will see things in our land that they have not seen. You will be able to explain things to them about which they have been baffled. I hope and believe also that our geologists—for, Mr. Chairman, I think I am right in assuming that you believe that our geologists are also men of great distinction—I believe that our geologists will be able to show you something, that they have made discoveries in this land that we own, that we love, that we are trying to understand; and that from their discoveries and from their experience you will be able to carry back to your own homes some new knowledge that will be applied by you when you return, and by your successors hereafter. And, therefore, as the result of this scientific gathering we may hope that we shall all profit—you from abroad and we at home—and that science will again justify herself even in the material returns that will be the outcome of these gatherings. But also I welcome you as representatives of science pure and simple, not merely applied. The world at large is divided by geographical boundaries; nations are separated by prejudices; they are divided by traditions, and language is a barrier which can be leaped over by only a few. But within this gathering of nations there is also the commonwealth of learning and of science, an empire that is each day adding new states, new provinces, new departments, new municipalities; an empire that is one in its language, one in the spirit that pervades it, an empire that has common traditions and that has common hopes. And as members of this empire of learning we welcome you from the world within. You represent science, and science surely to-day is one of the beneficent factors in this civilization of ours. Science, with its many rills and streams issuing from the same hills and flowing to the same ocean, is surely bringing down in these rills and streams a rich deposit of fertile soil to be overlaid on the lowlands of earth, which has been brought from the rugged edges of the mountain tops and is providing a finer soil on which a more beautiful, more contented, a more peaceful home may be found for humanity at large."

La parole est donnée à M. Tietze:

Vos Excellences, Mesdames, Messieurs:

C'est à ma qualité d'ancien président du Congrès géologique international, c'est-à-dire de la neuvième session de ce Congrès, qui se tenait à Vienne, que je dois, pour la deuxième fois, l'honneur de participer officiellement à l'ouverture d'une session de notre Congrès en Amérique. La première fois, cet honneur m'incombait au Mexique, ce qui paraissait naturel, parce que la session du Mexique suivait celle de Vienne, mais comme il n'y a pas d'autre ancien président dans l'assemblée d'aujourd'hui, c'est également à Toronto, que je dois, pour ainsi dire, réunir dans ma personne le passé de nos Congrès et le présent. Du reste, j'ai assisté, il y a vingt-deux ans, aussi au Congrès de Washington, comme délégué de mon pays. Je ne suis donc pas tout à fait étranger à ce nouveau monde qui, géologiquement parlant, pourrait peut-être, être nommé plutôt l'ancien, au moins pour une grande partie de son sol.

En me rappelant ainsi le passé et l'histoire de nos Congrès, il me convient à faire ressortir maintenant le fait que le Canada avait déjà invité les géologues de se rassembler ici. C'était lors de notre session en Autriche. L'assemblée votait alors pour le Mexique, et si le dernier Congrès de Stockholm a accepté l'invitation réitérée de nos confrères du Canada, il n'a fait que s'acquitter d'une dette morale contractée déjà à Vienne, il y a dix ans. Nous devions cela à nos confrères canadiens.

Mais nous ne sommes pas venus ici seulement pour remplir un devoir de politesse ou de courtoisie internationale, nous sommes venus de bon cœur et avec plaisir, parce que c'était une occasion, pour tous les géologues, d'apprécier le travail, aussi précieux que considérable, de nos confrères d'ici, qui ont fait tout leur possible pour faire connaître, au moins dans un sens préliminaire, les progrès géologiques de ce vaste pays.

Nous les remercions de ce qu'ils ont accompli pour la science et spécialement du travail qu'ils se sont imposé pour préparer ce Congrès. Mais nous remercions aussi les autorités de ce pays, le Gouvernement du Canada, le Gouvernement de la province d'Ontario, les représentants de la ville hospitalière de Toronto et de l'Université, de l'appui qu'ils ont donné à l'organisation de nos travaux, et en même temps nous exprimons le plus profond respect pour l'Auguste Protecteur du Congrès, Son Altesse royale le DUC DE CONNAUGHT, dont le nom a contribué beaucoup à la splendeur de cette réunion.

Permettez-moi, mesdames et messieurs, d'ajouter à ces remerciements un mot, qui ne me semble pas inutile en la présente circonstance. Si nous nous sommes réunis ici, nous n'avons pas seulement le désir de connaître les progrès de nos collaborateurs en science, les progrès ne représentent qu'une partie du développement étonnant général que le Canada a pris dans les derniers temps, et il me semble qu'il nous faut rendre hommage à ce développement en exprimant nos meilleurs souhaits pour l'avenir de ce grand pays.

L'adresse suivante est lue de la part de la SOCIÉTÉ ROYALE DU CANADA:

Mr. President and Members of the International Geological Congress:

In welcoming the International Geological Congress to this country the Royal Society of Canada is highly appreciative of the honour the presence of so distinguished a body of scientists bestows on the people of this Dominion.

The acceptance of an invitation to hold this XIIth session of the Congress here is a significant recognition by the members of the Congress of the prominent position the Dominion of Canada has taken not only in the commercial world but also in the realm of science.

The many and varied geological problems presented by Canada's broad expanse from the Atlantic to the Pacific will prove a fruitful source of study during the excursions, and will provide abundant material for future thought. The vast mineral deposits of the country will receive that close and particular attention that their great extent and richness call for.

The Royal Society has, in the past, included in its membership geologists of world-wide reputation whose names are familiar to all. At present it is keeping pace with the rapid growth and development of the country, and is successfully carrying on the work entrusted to it. The Royal Society is wholly cognizant of the many important and varied results that will accrue from the present session of the Congress, and assures the members of a hearty and hospitable reception throughout the length and breadth of the Dominion.

In the name, therefore, of the Royal Society of Canada we bid you welcome in the knowledge that your sesssion in Toronto and the excursions through the various provinces will prove of the greatest interest, and be productive of important results.

JAMES WHITE, F.R.S.C.
LAWRENCE M. LAMBE, F.R.S.C.
HENRY M. AMI, F.R.S.C.
Delegates.

C'est ensuite M. BÄCKSTRÖM qui parle:

Monsieur le Président du Douzième Congrès Géologique International:

Le Baron DE GEER, m'a chargé de vous exprimer ses très vifs regrets de ne pouvoir assister à la présente session du Congrès, et il m'a prié de déposer en son nom ses fonctions de Président.

Permettez-moi aussi, au nom du Comité exécutif du Onzième Congrès et surtout au nom des seuls membres de ce Comité qui soient ici, M. SJÖGREN et moi, de vous souhaiter, Messieurs les membres du Comité Exécutif du Congrès Canadien, que rien d'imprévu ne vienne diminuer le succès de ce Congrès que vous avez si diligemment préparé. Nous souhaitons en particulier la plus grande réussite aux excursions qui vont parcourir votre pays, ce pays si vaste, si plein d'intérêt pour tous les géologues, et si beau, surtout à nos yeux de suédois, qui venons d'un pays septentrional, la nature duquel ressemblant à celle de votre patrie que nous avons appris à aimer depuis notre enfance.

Le Secrétaire général, au nom de M. ANDERSSON, Secrétaire général du XIe Congrès, fait connaître les noms des membres du Bureau du XIIe Congrès proposés pour le Conseil.

Les nominations sont approuvées. (Pour la composition du Bureau voir page 14.)

Son Excellence:

"Il me reste maintenant à demander au nouveau Président de vouloir bien prendre ma place."

M. FRANK ADAMS, Président, s'installe au fauteuil et dit:

"Votre Excellence, Mesdames et Messieurs:

Je suis heureux de vous remercier bien sincèrement pour l'expression de confiance que vous avez bien voulu me manifester en m'appelant à l'honorable fonction de président du Douzième Congrès international géologique.

En ma qualité d'ancien président du Comité exécutif, j'ai le plaisir de vous souhaiter tout particulièrement, la bienvenue, au nom des géologues du Canada.

L'organisation du Onzième Congrès, tenu en Suède, a été si parfaite que, dès le début, notre Comité a compris la difficulté d'en suivre le modèle, surtout à cause de l'énorme étendue du Dominion.

De plus, tout en soumettant un tableau géologique presque complet ainsi qu'un relevé assez considérable des ressources économiques, nous ne pouvons pas encore présenter des résultats de recherches géologiques aussi détaillés que ceux dont disposèrent, pour l'étude, les vieux pays.

Le Canada, d'un autre côté, vous offrira un champ d'observation particulièrement attrayant, par le fait que les recherches géologiques s'étendent sur une si vaste échelle en notre pays, embrassant l'étude d'un territoire immense.

Mesdames et messieurs, vous êtes tous, cordialement bienvenus au Canada.

Maintenant, mesdames et messieurs, je prierai le Secrétaire général du Congrès de communiquer certains renseignements et faire connaître les mesures prises pour le fonctionnement de la session.

LE SECRÉTAIRE GÉNÉRAL:

"Mr. President, ladies and gentlemen:

It is a very great honour, a matter of national pride in a young country such as ours, to have in its midst a Congress of world-renowned scientists from all quarters of the globe. For the first time Canada is the centre of a real world congress. It perhaps may cause the dream of some of us enthusiastic Canadians, of Canada becoming the centre of the British Empire, to be extended to embrace the world for at the present moment we are, of course, the centre of the geological world.

As the President has just mentioned, when, in 1910, the Eleventh Congress decided to hold its Twelfth Session in Canada we were delighted with the opportunity of entertaining so distinguished a gathering, but this delight was tempered by the realization of the difficulty in a young country of adequately arranging for such a large and important gathering particularly following the wonderfully successful meeting organized by the distinguished representative from the Eleventh Congress, Mr. BÄCKSTRÖM and his colleagues, which set a standard that it would be difficult for anyone, and impossible for us, to reach. The excursions are recognized to be the most effective instruments for the accomplishment of the objects of the Congress, as through them the delegates from the four corners of the earth are in personal contact, unfettered by formality; and under the inspiration of the phenomena presented in the field they freely exchange views with each other and give one another the benefit of their personal experience and knowledge. In a country of such great and varied geological interest as Canada, and so comparatively unknown to outside geologists, we felt that, if excursions were successfully arranged, the Congress would be in some measure repaid for its choice of Canada as its meeting-place. Consequently our efforts have been largely expended on preparations for the excursions. I need not point out that this has been no light undertaking. The excursions planned before, during and after the Congress cover a distance in the neighbourhood of 20,000 miles, and afford delegates an opportunity to see typical examples of the most accessible features of geological interest and obtain a clear idea of the geology and natural resources of the northern half of the North American continent. The excursions in eastern and central Canada have been already completed, or will be during the session. After the session western Canada will be visited, and I am sure you will find these western excursions of exceptional interest. We are particularly pleased to be able to offer you an excursion up the Pacific coast to the St. Elias Alps and to the Yukon.

Following the precedent of the last Congress the topics selected for discussion at this session are those which would naturally arise or would be well illustrated on the excursions. The main topic is "The Coal Resources of the World." As a basis of discussion of this subject we have been able, thanks to the very hearty co-operation of various distinguished specialists and of the countries interested, to publish for the Congress a very large monograph on the subject, which we hope will be not only of use to the Congress but of permanent value to the public at large.

As I have mentioned, the efforts of the Executive Committee have been largely confined to the excursions; the success of the session rests with the members and delegates, but with such a gathering of noted authorities and workers in geology, I feel confident that a very interesting and valuable session will result.

It is a pleasant duty to record the hearty thanks of the Executive Committee to all who have contributed support. We have to thank Field Marshal, His Royal Highness the DUKE OF CONNAUGHT for graciously acting as Honorary President. We have to thank His Excellency Sir CHARLES FITZPATRICK for opening this meeting; the Dominion Government, the Governments of Ontario, Quebec, Nova Scotia and British Columbia, and public institutions and private individuals for the contributions and help that have made it possible to hold the Congress in Canada.

Special mention must be made of the generous assistance of the Dominion Government, which has not only contributed largely to the funds of the Congress but has assisted also in every other possible way.

To the distinguished delegates and members who are gracing this session with their presence we tender a cordial welcome and sincere thanks. The men who have made the geological science of to-day, your visit will do much to inspire the young geologist and stimulate the science in this country. The greater part of Canada is unexplored, its resources undeveloped. It is of vast importance to the country and to the world at large that these resources should be wisely developed. Geology can render much assistance in discovering and making known and intelligently developing these resources. By your presence here and by your interest in the geology of Canada you are contributing to this highly desirable end.

La séance est levée.

SECONDE SÉANCE.

Séance consacrée à la discussion sur Topique N° 1, "Les ressources houillères mondiales."

7 août.

La séance est ouverte à 3 h. de l'après-midi sous la présidence de M. TH. TSCHERNYSCHEW, MM. T. C. DENIS et CHARLES CAMSELL agissant comme secrétaires.

Le président rappelle la décision prise par le XI^e Congrès à Stockholm à l'effet de faire préparer sous sa direction une estimation des ressources houillères mondiales. Ce travail est maintenant terminé et forme un ouvrage en trois volumes accompagnés d'un atlas. Il prie M. BROCK de donner un aperçu de l'ouvrage.

M. BROCK dépose entre les mains du Congrès la monographie complète, et profite de l'occasion pour remercier tous les collaborateurs de ces volumes. Il regrette que, dans certains cas, afin de ne pas en faire un ouvrage trop volumineux et en raison du fait que certains rapports sont arrivés très en retard, il ait fallu condenser une partie des matières et éliminer un bon nombre des cartes. Et M. BROCK continue ainsi:

This monograph, which is intended to form a companion work to the *Iron Ore Resources of the World* published under the auspices of the Eleventh Congress, consists of three quarto volumes of 1,360 pages in all, illustrated by upwards of 175 maps and figures and accompanied by a 68-page atlas of geologically coloured maps.

The work is edited by Messrs. MCINNES, DOWLING and LEACH of the Geological Survey.

In the main body of the monograph there are reports on 64 countries, varying in length from over 100 pages for some of the countries with important reserves of coal to a few pages in the cases of those with less important reserves. The greater number of the reports are in English, ten are in French and six in German. In the *Summary of the Reports*, which appears in the first volume, all the reports are summarized in English by the editors.

Mr. BROCK, the General Secretary of the Congress, contributes the preface of the book, in which is explained the conditions under which the publication was undertaken. Attention is called to the very cordial support given by Geological Surveys and other similar departments of government throughout the world. Through official sources such as these the greater part of the information has been gained, although certain very valuable contributions are from the pens of specialists unconnected officially with the fields about which they write, but who were considered to have had unequalled opportunities for the study of these fields. An instance of a contributor of this character is Dr. NOAH DRAKE, who writes on the coal resources of China and whose long university experience in China has given him opportunities which few have had for the study of China's mineral resources.

Owing to the lack of uniformity in the usage of the different countries of the world in regard to the commercial classification of coals into anthracite, bituminous coal and lignite, it was found necessary to adopt an arbitrary classification which might be used by all and thus make the results more easily comparable. A committee to whom the subject was referred drew up a scheme of classification dividing the coals into A, B, C and D groups with various subdivisions based mainly on composition and heating value. In this scheme A roughly corresponds to anthracite, B and C to bituminous coal and D to sub-bituminous coal, brown coal and lignite. With few exceptions the reports submitted conform to the classification asked for, as they do also to the other requirements regarding the depths to which computations were to be carried and the division of the reserves into actual, probable and possible reserves, though in some cases the information at hand has not been full enough to warrant strict compliance with the specified form on all these points.

In the *Introduction* Mr. DOWLING summarizes the results, dealing first with the distribution of coal in the various geological systems. The range of important fields in the Palæozoic extends from Lower Carboniferous, in the case of the fields of central Russia, Scotland and the Arctic Islands, through Upper Carboniferous, to which the very large deposits of western Europe and eastern America appertain, to Permo-Carboniferous, in which are embraced most of the very extensive fields of China, India and Australia. The Mesozoic, though not so widely spread, contains very important coal basins in Europe, western America and Asia. The Tertiary contains deposits of importance in most parts of the world, including fields in central and western Europe, in Japan, in New Zealand and throughout the Great Plains region of North America.

The total reserves of the world, compiled from all the reports received, amount to 7,397,533 million tons, of which nearly 4,000,000 millions are bituminous coals, nearly 3,000,000 millions are brown coals of various grades and nearly 500,000 millions are anthracitic coals. Of the anthracite coals Asia with the great Chinese fields has by far the largest supply of any of the great continental divisions, furnishing 407,637 million tons; in bituminous coals America with 2,271,080 million tons leads by a great margin, as she does also in the various grades of brown coals. The world's production of coal for the year 1910 was about 1,145 million tons, so that, though much must be allowed for loss in mining and for areas that for various reasons cannot be economically mined, there still remains many hundreds of years before exhaustion of the supply may be looked for. Taking up the individual countries, however, it is found that in more than one case the end is in sight.

In other tables the reserves of the different continental areas are classified as actual, probable and possible reserves, and in others the reserves of the individual countries are classified in a more particular way, thus Canada is shown to have actual reserves, in million tons:

Nova Scotia		Class B 2,138	Class C	50
Alberta	Class A 668	Class B 3,209	Class D	384,908
British Columbia	Class A 7	Class B 23,764	Class D	60

or totals of A 675; B and C 29,161; D 384,968 million tons, and to have in addition probable reserves of A 1,183; B and C 254,500; D 563,182 million tons.

The production of Canada at the present time is only in the neighbourhood of twelve million tons annually and though the output may be expected to increase rapidly, the figures given above show that actual exhaustion of the supply lies very far in the future.

Following the *Introduction* is a *Summary of the Reports* by the editors. In this a resumé in English of each of the extended reports in the volumes is given, together with a brief compiled statement regarding a number of countries, including among others Greenland, from which comprehensive reports were not received. Lists are given also of the countries from which statements were received that they have no known coal resources.

The main part of the volumes, comprising 1 266 pages, is taken up by the extended reports received from the different countries of the world which have coal resources in one form or another. A glance over the index is sufficient to show how rare it is to find in any quarter of the globe a country without fossil fuel of some kind. Volume I contains reports from the Islands of Oceania, including besides the Australasian islands, the Philippines, Netherlands India and the Antarctic continent, which is dealt with by the well-known authority, Dr. DAVID; also reports from Asia. Under Asia is a very full report on China by Dr. NOAH DRAKE, supplemented by one covering portions of China in detail and illustrated by 16 figures of different coal fields, by KINOSUKE INOUYE of the Imperial Japanese Survey. The reports on China are very valuable contributions to our knowledge of the coal reserves of the world, since each of them contains much information not hitherto published. The Japanese report contains information acquired by various officers of the Japanese Geological Survey corps; articles by INOUYE on Corea, Manchuria and Japan, all illustrated by figures and containing much new information; a very well written paper by H. H. HAYDEN, Director of the Indian Geological Survey, on British India and neighbouring countries, and reports on the Malay States, Siam, Persia and French Indo-China.

Volume II contains reports concerning Africa, North, South and Central America, the West Indies and part of Europe. Under Africa there is a report on the States of the South African Union, furnished by the Department of Mines, which contains good descriptions of their coal-bearing Karroo system, which lies upon a glacial conglomerate; also reports from eight other divisions, including Southern Nigeria, Rhodesia and the Belgian Congo. North America begins with a report by J. P. HOWLEY on the coal areas of Newfoundland, which, although they have not yet been exploited, Dr. How-

LEY thinks are worthy of development and constitute extensions of the Nova Scotian fields. The article on Canada which follows is furnished by D. B. Dowling, who deals with the coal fields in order from east to west, describing each in turn and tabulating its actual and probable reserves. Mr. Dowling estimates a total reserve in Canada of all classes of coal of 1,234,269,310,000 metric tons. The fields in the United States are taken up by M. R. Campbell of the United States Geological Survey. Mr. Campbell estimates that the original content of the United States coal fields, not including Alaska, was 3,225,394,300,000 metric tons, of which up to 1910, 11,220,532,500 tons had been exhausted. Alaska is given separate treatment by A. H. Brooks and G. C. Martin, who consider that the known fields contain nearly 20,000 million tons, over half of which is lignite. Robert T. Hill, late of the U. S. Geological Survey, contributes the paper on Mexico.

For Central America, the West Indies and South America there are reports from Honduras, Panama, Trinidad, Columbia, Argentine and Chile. The Chilean fields, which seem to be all of Tertiary age, are described by Miguel R. Machado, and the Argentine fields by E. Hermitte, Director of the Argentine Division of Mines, Geology and Hydrology.

The rest of Volume II is taken up with a part of the European reports. Great Britain is treated of by Dr. Aubrey Strahan of the British Survey and Ireland by Grenville A. J. Cole and E. St. John Lyburn. The greater part of the coal is bituminous and the total possible reserve for the Kingdom is estimated to be 189,534,749,920 metric tons. The report for Portugal is from the Department of Agriculture and that for Spain by Luis de Adaro.

France is written of by M. A. Defline, one of the most eminent of the French Corps of Mining Engineers, who estimates for France a reserve of coal of 17,584,625,000 tons, a large part of which is of bituminous grade. The French report is very fully illustrated by a series of geologically coloured maps in the atlas, showing all the principal coal fields of France in detail.

Other papers of exceptional interest in the second volume are those of Switzerland and Turkey; the former for the reason that it presents the case of a country whose resources in coal are almost depleted, the total actual reserve of Switzerland amounting to only 4,000 tons of anthracite and 500 tons of bituminous coal. Turkey, on the other hand, which is dealt with by Leon Dominian, M.E., has very considerable amounts of brown coal in her Asiatic provinces and deposits of cannel-like bituminous coal in the province of Adrianople. Reports from Italy, Greece and Bulgaria complete Volume II.

The 386 pages of Volume III contain the reports from the remaining 14 countries of Europe. All these reports are of a most interesting character and all are the work of most eminent specialists in the various countries to which they refer: Denmark's contribution is by Dr. N. Hartz, that of the Netherlands by W. A. J. M. van Waterschoot van der Gracht and that of Belgium by Armand Renier, M.E.

Germany contributes a most exhaustive description of the different coal fields of the Empire, written by twelve distinguished geologists, each describing a district with which he is particularly familiar. Very full tables of reserves accompany the German report. Summarized, they give for Germany a total actual reserve of 94,865,000,000 tons of *stein*-coal and 9,314,300,000 tons of brown coal, with, in addition, a large probable reserve.

The interesting report on Hungary is by Prof. Dr. Lóczy de Lócz and Dr. Charles de Papp, and that for Austria by Dr. Petrascheck of the Austrian Geological Survey. Each of these reports is illustrated by maps, that of Austria being accompanied in the atlas by a very valuable set of coloured maps which were specially prepared for the work by Dr. Petrascheck. Bosnia and Herzegovina, Servia and Roumania are represented by papers contributed, in each case, by men who are in a position to speak with authority for each country.

Sweden, which has considerable resources in bituminous coal, is described by Dr. Edward Erdmann. Norway's possible coal reserves, which are confined to some of the northern islands, are dealt with by Dr. Hans Reusch, and the interesting fields of Spitzbergen are the subject of an additional, special paper by Bertil Högbom, who estimates for that island a probable reserve of bituminous coal of 8,750,000,000 tons.

The volume closes with a paper, in English, on the coal fields of Russia, including Russia in Asia. Dr. Th. Tschernyschew, Director of the Russian Geological Survey, who in an introduction summarizes the Russian report, estimates for the Empire a probable reserve of coal of all grades of 233,997,-000,000 tons of which 18,001,000,000 tons are of anthracitic coals.

For the purposes of the report the Russian dominions are divided into thirteen districts, which are described separately, each by an author who has had special opportunities for studying the particular field he describes. The collection of the information for this report,—and the same is true of many reports contained in the volumes,—entailed a large amount of field work undertaken for the special purposes of the investigation, so that the 120 pages devoted to Russia are all of intense interest.

The reports contained in the volumes are illustrated by upwards of 175 maps and figures and by many tabulated statements.

The Atlas, which presents a very bright and attractive appearance, contains 68 pages of maps, most of them in colours. It opens with a map of the world in hemispheres, geologically coloured to show the distribution of Tertiary, Mesozoic and Palæozoic coals throughout the world. Especially noteworthy among the plates are, perhaps, the coloured maps of China, Corea, Manchuria and Japan, those of Austria and of France, the eight maps of the coal fields of Canada and those of Servia, Roumania and Sweden. The Atlas closes with a geologically coloured map of the island of Spitzbergen.

M. J. M. Gordon parle longuement de la classification de la houille.

M. H. M. Cadell, soulevant un point d'ordre, déclare que malgré tout l'intérêt que présente la classification de la houille, cette question n'a aucun rapport avec la présente discussion.

M. J. W. Evans parlant des houilles africaines fait remarquer que celles de l'Afrique méridionale et centrale sont de l'époque permienne, tout comme les houilles plus anciennes de l'Inde. Il fait l'éloge des travaux de Andrew et Bailey dans le Nyasaland et de Parkinson, Kitson et Thiele dans la Nigéria méridionale, dont les résultats sont consignés dans sa contribution à la monographie de la houille. Il explique que si, dans son article, il n'a pas suivi la classification officielle, c'est parce qu'il n'a pas reçu la circulaire donnant les intructions à cet effet.

La parole est à M. Defline.

M. Defline: Je résume les principeux résultats de l'étude des ressources de charbon de France.

La France est un pays relativement pauvre en combustibles minéraux. Par contre, les gisements distincts, qui y sont nombreux, se rattachent à des types variés, et leur constitution est parfois très complexe, de sorte que peu de pays peuvent offrir sur ce sujet un champ d'étude plus intéressant pour les géologues.

J'ai décrit dans mon rapport les gisements de houille et de lignite actuellement connus en France. J'ai donné ensuite une évaluation de leurs réserves, et j'ai fait connaître les quantités de combustible qui en ont été extraites avant l'année 1[illegible] ces dernières atteignent 1,500,000,000 de tonnes environ.

Dans l'évaluation des réserves, j'ai fait une distinction entre celles qui se trouvent à une profondeur inférieure à 1,200 mètres et celles qui sont entre 1,200 et 1,800 mètres. Je suis arrivé ainsi aux évaluations suivantes, exprimées en millions de tonnes:

		Houille	*Lignite*	*Ensemble*
Réserves à moins de 1,200 mètres.	Certaines	1,203	301	1,504
	Probables,	3,891	110	4,001
	Possibles	1,885	921	5,806
		12,982	1,632	14,614
Réserves possibles entre 1,200 mètres et 1,800 mètres		2,970	. .	2,970
Réserves totales		15,952	1,632	17,584

Le plus important de beaucoup de nos bassins houillers est celui de Valenciennes, situé dans le Nord de la France dans le prolongement du bassin belge du Hainault. Parmi les autres bassins ayant une certaine importance, je citerai les bassins stéphaniens de St. Etienne, d'Alais et de Blanzy situés dans le plateau central, et les gisements de lignite crétacé de Fuveau en Provence. Les réserves certaines et probables de ces bassins principaux ont été évaluées comme suit en millions de tonnes:—

Valenciennes	6,800
St. Etienne	411
Alais	113
Blanzy	159
Fuveau	700

Pour l'ensemble des bassins, les réserves certaines et probables situées à une profondeur inférieure à 1,200 mètres s'élèvent à 8,801,000,000 tonnes. La production de la France ayant été de 39,229,591 tonnes en 1911, ces réserves permettraient d'alimenter l'extraction actuelle pendant 221 ans. Même en admettant une certaine progression de l'extraction, il ne paraît pas douteux que ces réserves suffiront pendant plus de cent ans.

M. P. J. Krusch, à qui la parole est donnée ensuite, exprime des regrets de la part de M. Böker de n'avoir pu assister au Congrès, et présente au nom de celui-ci la communication suivante sur le sujet:

Einige Bemerkungen zu der Diskussion über die Kohlenvorräte der Welt.

1. *Hinsichtlich der Methode der Vorratsermittlung.*

Der von der Kongressleitung vorgeschlagenen Ermittlungsmethode, der Einteilung in die Gruppen I und II und deren Unterteilung in actual, probable und possible reserves kann als durchaus zweckmässig nur zugestimmt werden.

Die in dem Kongressvorschlag gewünschte Angabe des Vorrates *eines jeden einzelnen Flözes* ist jedoch [illegible] undurchführbar

(*a*) bei durchhaltenden ([illegible]) Flözen z. B. Westfalen, wenn sie, wie oft, in sehr grosser Anzahl [illegible] sind, in solchen Fällen verbietet sich eine derartige Angabe schon aus Gründen der reinen Uebersichtlichkeit.

(*b*) bei nicht durch das ganze Becken durchhaltenden Flözen (besonders bei Flözen limnischen Charakters), wenn sie ebenfalls in grösserer Anzahl vorhanden sind, einem raschen Wechsel in der Mächtigkeit unterworfen und vielfach selbst in kürzerer Entfernung nicht identifizierbar sind (z. B. Saarbezirk, Niederschlesischer Bezirk). In solchen Fällen kann nur der Vorrat *ganzer Flözgruppen* (Formationsstufen) angegeben werden, wobei in den Fällen zu *b* der *durchschnittliche* Kohleninhalt der betreffenden Stufe zugrunde gelegt werden muss.

Die starke Betonung des *rein zahlenmässigen* Wertes der *Flözmächtigkeit* in dem Kongressvorschlag (1 und 2 Fuss) hat ihre Berechtigung für die Ziele der Kongressleitung, die eine möglichst weitgehende Einheitlichkeit in den Vorratsermittlungen der einzelnen Länder anstreben muss; für eingehendere Bearbeitungen hat sie jedoch insofern einige Bedenken, als die Mächtigkeit für die *Bauwürdigkeit* zwar sehr wichtig, aber nicht in jedem Falle ausschlaggebend ist. Bei der deutschen Vorrats ist daher im allgemeinen nur *eine* Vorratsgruppe unterschieden, dafür aber auch nur der Vorrat der unter den heutigen Verhältnissen *tatsächlich bauwürdigen* Flöze eingesetzt worden. Die Ermittlungen der *"bauwürdigen"* Vorratsmengen muss aber das praktische Endziel aller solcher Untersuchungen sein. Die Bauwürdigkeit ist von vielen Faktoren abhängig, von denen die Flözmächtigkeit nur ein einzelner ist, der zu dem noch bei einem bestimmten Stande der Bergbautechnik in jedem Kohlenbezirk verschieden gross ist oder sein kann, sich also nicht in allen Fällen einfach den festen Grenzen von mindestens 1 oder mindestens 2 Fuss des Kongressvorschlages anpassen lässt.

Für spätere ähnliche Arbeiten dürfte es sich m. E. bei ähnlichen Vorratsermittlungen empfehlen, von vornherein vorzuschreiben, dass nicht nur Zahlenangaben über die Grösse der Flächen der betreffenden Mineralvorkommen zu machen, sondern ausserdem *Karten- und Profilskizzen* beizugeben sind, aus denen neben der jeweilig bekannten Verbreitung der Mineralvorkommen vor allem *die bei der Berechnung berücksichtigten und nicht berücksichtigten Teile der Gesamtverbreitung* zu erkennen sind. Sofern verschiedene Vorratsklassen unterschieden werden, sollte die vorgeschlagene kartographische Festlegung der Berechnungsfläche sich auch auf die einzelnen Vorratsklassen erstrecken. Wie die Erfahrung immer wieder bestätigt, werden die an sich dringend wünschenswerten Vergleiche mit älteren Vorratsberechnungen und Schätzungen unmöglich oder zum mindesten doch ausserordentlich erschwert und zeitraubend, wenn früher eine solche kartographische Festlegung unterblieben ist.

Ferner dürfte sich m. E. bei späteren derartigen grossen Vorratsermittlungen die Beigabe wenigstens des wichtigsten Zahlenmateriales zur *wirtschaftlichen Beurteilung* der betreffenden Lagerstättenbezirke dringend empfehlen. Eine ausführlichere und im einzelnen begründete Darlegung hierüber, die aus Mangel an Zeit vor dem Kongress nicht mehr beendigt werden konnte, soll in dem Compte Rendu des XII Int. Geol. Kongresses folgen. Hier seien nur einige Punkte aufgeführt, über die m. E. *kurze* Ausführungen und Zahlentafeln in solchen Untersuchungen dringend wünschenswert erscheinen:

Statistik der Förderung der Einzelbezirke nach Menge und Wert (am Erzeugungs- und tunlichst auch am Verbrauchsorte). *Statistik der Förderung des ganzen Landes einschliesslich der Ein- und Ausfuhr* (alles nach Menge und Wert) sowie des *Verbrauchs* des Landes, sowohl absolut wie auf den Kopf der Bevölkerung, tunlichst auch Trennung des Verbrauches nach den wichtigsten Verbrauchergruppen, wie z. B. Industrie, Schiffahrt, Haushaltung u. s. w. Ferner statistische Angaben über die *Belegschaft* und die *Löhne* in den einzelnen Bergbaubezirken u. s. w. Hierbei würden zweckmässig die Zahlenwerte nicht für die politischen Einheiten eines Landes, sondern, wenn irgend möglich, für die *natürlichen Lagerstättenbezirke*, die ja häufig sich über mehrere politische Einheiten erstrecken, gegeben. Diese Zahlenwerte sollen die Entwicklungstendenz, wenigstens der letzten Jahrzehnte erkennen lassen. Erwünscht sind ferner kurze Angaben über die Bedeutung der betreffenden Lagerstättenbezirke; ob diese also nur für den Lokal- oder auch für den Landeskonsum in Frage kommen oder gar auf dem Weltmarkt eine wesentliche Rolle spielen. Falls in einzelnen Ländern *Frachtfragen, Zollverhältnisse* oder *Besteu ...smassnahmen* von wesentlichem Einflusse auf die Entwicklung der betreffenden Lagerstättenbezirke sind, wären auch hierüber kurze Ausführungen wünschenswert. Die bei Erfüllung dieser Wünsche für die Bearbeiter der einzelnen Länder sich ergebende Mehrarbeit dürfte nicht sehr bedeutend sein, zumal wenn diese Punkte im einzelnen schon von vornherein in den Vorschlägen der betreffenden Kongressleitung angegeben werden. Für die Leser, besonders aber für die ausländischen Leser, bedeutet die Beigabe solcher wirtschaftlichen Angaben einen sehr grossen Vorteil, da letzteren erfahrungsgemäss das wirtschaftlich-statistische Material in den meisten Fällen nur sehr schwer zugänglich ist. Bei der nach einheitlichen Gesichtspunkten erfolgenden Bearbeitung in den Kongresswerken, die ja nur in den allen gebildeten geläufigen Kongresssprachen erscheinen, fällt auch das sonst oft störende Moment der Nichtkenntnis der betreffenden Landessprache fort. Auch die durch diesen Mehraufwand an Arbeit und den grösseren Umfang der Publikationen entstehenden grösseren Herstellungskosten dürften durch den alsdann sich ergebenden grösseren Kreis der Abnehmer reichlich aufgewogen werden.

II. *Hinsichtlich der Kohlenklassifizierung.*

Voll und ganz muss man m. E. auch der Absicht der Kongressleitung zustimmen bei dem grossen Unternehmen einer Weltkohleninventur die Gruppierung der Kohlenvorräte tunlichst *nach einheitlich festgelegten Kohlenarten* vornehmen zu wollen. Es fragt sich nur, ob das für diesen Zweck vorgeschlagene neue Klassifikationsschema für alle Fälle geeignet ist.

Der Kongressvorschlag basiert ausschliesslich auf rein chemischer Einteilung; nun ist aber die Substanz, die wir als Kohle bezeichnen, ein derartig kompliziertes Gemenge in sich auch noch wahrscheinlich kompliziertest aufgebauter Kohlenwasserstoffe. Wir wissen doch heute überhaupt noch nicht, wie die C, H, N, O und S Atome zu Molekülen in der Kohle zusammengruppiert sind, wir wissen auch noch gar nicht, in welchen Formen und nach welchen Gesetzen eine Umlagerung und Neugruppierung der einzelnen Atome bei der chemischen Analyse, bei der Verkokung, überhaupt bei den Manipulationen, die wir bei der Untersuchung und Verwendung der Kohle mit dieser vornehmen, stattfinden. Die Elementaranalyse sagt uns ja nur, dass in Summa in der Gesamtheit der verschiedenartigst zusammengesetzten einzelnen Kohlenwasserstoffe so und soviel Prozent C, H, N, O und S enthalten sind—aber nichts weiter. Nun können aber zwei Kohlen, die nach der Elementaranalyse gleiche oder sehr ähnliche Zusammensetzung aufweisen, sehr verschiedene technische Eigenschaften haben; umgekehrt können Kohlen gleiche Eigenschaften bei sehr verschiedener chemischer Zusammensetzung zeigen. Deutet dieser Umstand schon darauf hin, dass ein ausschliesslich nach chemischen Gesichtspunkten aufgestelltes Klassifikationsschema nicht das Ideal ist, so ergeben weitere Ueberlegungen, dass eine alle Interessen befriedigende Klassifizierung auch die rein wissenschaftlich-geologischen Interessen wie diejenigen der Praxis berücksichtigen müsste; sie müsste auch in eine Form gebracht werden, die bei aller wissenschaftlichen Gründlichkeit doch auch für die Kohlenverbraucher leicht verständlich wäre. Ob das in Vorschlag gebrachte Klassifikationsschema für nichtdeutsche Kohlen zweckmässig ist, entzieht sich meiner Beurteilung; für deutsche Kohlen vermag ich jedoch in ihm keinen besonderen Fortschritt zu erkennen. Diese Anschauung wird übrigens, was ich nicht unerwähnt lassen möchte, auch von bedeutenden Kohlenchemikern geteilt.

Da mir nach allem das zu erstrebende Ziel heute noch unerreichbar fern erscheint, möchte ich es für zweckmässiger halten,—statt eine neue, nicht voll befriedigende Neueinteilung einführen zu wollen— vorläufig noch bei den bisherigen Bezeichnungen und Gruppierungen zu bleiben, die in den einzelnen Ländern, zwar in sehr verschiedenem Masse, im Grossen und Ganzen jedoch den Bedürfnissen der Praxis entsprechen. Wichtiger als eine neue Klassifikation scheint mir bei dem jetzigen Stande zu sein, dass Einzeluntersuchungen angestellt werden, dass also Bausteine gesammelt werden, von denen ein jeder sein Teil beitragen wird, uns der Erkenntnis näher zu bringen; Bausteine, die in ihrer Gesamtheit und in hoffentlich nicht zu ferner Zukunft alsdann den Bau einer Brücke ermöglichen, auf der Wissenschaft und Praxis gemeinsam das Ziel erreichen können und damit die heute noch unüberwindbar erscheinende Kluft überwinden. Es dürfte sich m. E. empfehlen, zunächst die Fragen zusammenzustellen, von denen eine Lösung wenigstens von Teilproblemen zu erwarten ist und dadurch die Arbeiten in bestimmte Bahnen zu lenken, und diesbezügliche Untersuchungen in den einzelnen Ländern anzuregen. Zur Erläuterung nur wenige Einzelbeispiele: Es wäre m. E. näher zu untersuchen, ob zwischen der chemischen Zusammensetzung und den etwaigen botanischen Verschiedenheiten des Ausgangsmaterials der heutigen Kohle und zwischen den verschiedenartigen geologischen Bedingungen, unter denen die Kohlebildung eingesetzt hat, (Humusbildungen, Sapropelbildungen u. s. w.) weitgehendere genetische Zusammenhänge bestehen; man würde vielleicht weiter kommen, wenn man neben der heute meist üblichen Durchschnittsprobe aus dem ganzen Flözprofil bei "Streifenkohlen" auch noch sorgfältige Analysen getrennt für die Glanz- und die Mattkohlenstreifen vornehmen würde und gleichzeitig das zahlenmässige Verhältnis der Beteiligung an dem Flözaufbau ermittelte und zu den technischen Eigenschaften der Flöze in Verbindung zu bringen suchte. Man müsste m. E. in den verschiedenen Kohlenrevieren einmal genauere Beobachtungen anstellen, ob ausser den vorerwähnten Momenten nicht auch etwa die petrographische Beschaffenheit der einzelnen Nebengesteinsschichten oder andere Faktoren von wesentlichem Einfluss auf die Herausbildung des Kohlencharakters gewesen sind. Haben wir doch mehrfach in derselben eng begrenzten Formationsstufe Kohlenflöze, die durchaus verschiedenes technisches Verhalten zeigen.

Bei der Beschäftigung mit der Kohlenvorratsermittlung und der dabei sich ergebenden Probleme sind die grossen Schwierigkeiten einer alle Gesichtspunkte befriedigenden Kohlenklassifizierung ja offenbar geworden; ich möchte jedoch glauben, dass diese am schnellsten überwunden werden konnen, wenn die zunächst erförderlichen Untersuchungen in den einzelnen Ländern nach einheitlichen systematischen Plane in die Wege geleitet würden.

M. A. E. Kitson fait au sujet de la houille brune de Victoria les remarques suivantes:—

The brown coal deposits of Victoria, Australia, are of great proportions and of wide distribution through the southern half of the State, principally in the basins of the Moe, Latrobe and Morwell rivers (central Gippsland), the Alberton and Welshpool districts (southern Gippsland), the northwestern side of Port Phillip, near Melbourne, and in the basins of the Werribee, Moorarbool, Upper Barwon and Gellibrand rivers (western and southwestern central Victoria).

They occur associated with Cainozoic gravels, sands, clays and, rarely, limestones, principally of the older and middle Cainozoic periods. Though in the Port Phillip area they are interbedded with marine deposits, probably Oligocene, they appear to be mainly of estuarine and lacustrine origin. The principal deposits may be regarded as occupying an area of at least 2,000 square miles.

At Maryvale, near Morwell, in the Latrobe valley, a bore sunk to a total depth of 1,110 feet showed an aggregate of 808 feet of brown coal, associated with clays and sands. This occurrence is the greatest known deposit of brown coal in the world. It consists of seven beds, with thicknesses in descending order of 29, 25, 49, 228, 265, 166 and 44 feet, the third and two succeeding beds (542 feet thick) being separated by two bands of clay, 6 feet in thickness.

Other deposits, varying from 20 to 193 feet, occur in several places, as shown on the map which I present. Some of the large deposits have natural outcrops; others occur under beds varying from 40 to 360 feet in thickness.

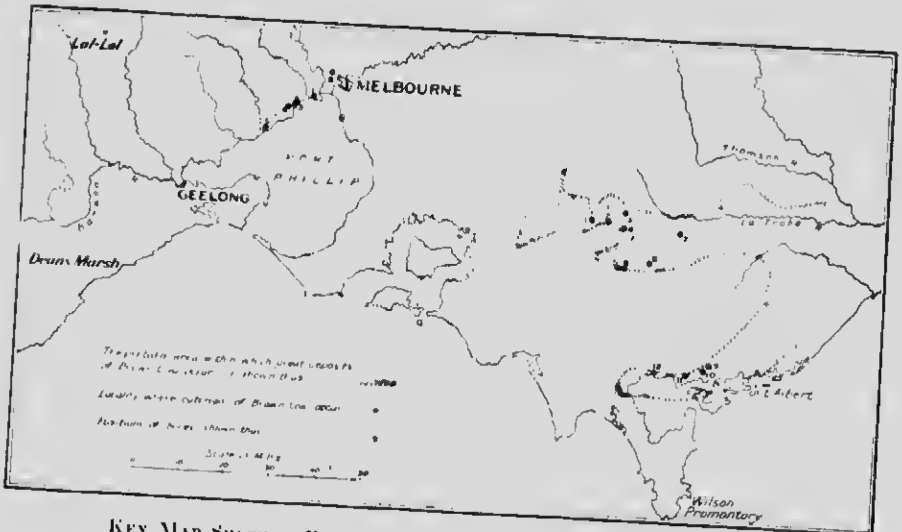
A large portion of the wide volcanic plain west of Melbourne is in all probability underlain, though perhaps not connectedly, by large deposits of brown coal, for near its northern margin, at Bacchus Marsh, two beds 24 and 20 feet thick are reported to have been found in Railway Department bores, while 20 miles to the southeast, near the shore of Port Phillip, the deposits are from 33 to 134 feet in thickness.

Most of the Victorian brown coal is of high quality, admittedly superior to that of Germany, where the industry is of such great importance. The superiority is in the lower amount of moisture and ash and the higher amount of carbonaceous matter.

In its raw and briquetted states the Morwell brown coal has calorific values of 8,228 to 9,540 B.T.U., respectively, while the calorific values of most of them are high.

The material is capable of being made into good briquettes without the aid of any binding matter, and it is eminently suitable for use in gas producers. For a useful comparative, general, analytical and economic description of some of the Victorian brown coals, reference should be made to the paper, "*The Utilization of Brown Coal,*" by P. G. W. BAYLY, A.S.A.S.M., published in the Proceedings of the Society of Chemical Industry of Victoria, August-September, 1908, which is based principally on the work of the late JAS. STIRLING and of the author of the paper.

La séance est levée.



KEY MAP SHOWING POSITION OF BORE-HOLES, VICTORIA, AUSTRALIA.

Bores northwest of Port Phillip

Bore No.	*Remarks.*
B.	Brown coal 8' at 221'.
1.	Brown coal 2' 4" at 202', 14' at 242', 4' 2" at 275', 2' at 291'.
2.	Brown coal 70' 5" at 350'.
3.	Brown coal 74' 0" at 348'.
4.	Brown coal 20' 0" at 363', 42' at 393', 13' at 435', 50' at 448'.
5.	Brown coal 33' 0" at 521'.

Boring at Lal-lal revealed 128' brown coal at 60', and 8' at 188'.

Boring at Deans Marsh. Thickness uncertain, probably 10' to 12'.

Bores in Bulu-Bulu County

Bore No.	*Remarks.*
1.	Average thickness 35' at 60' from surface.
2.	Thickness from 1' to 67'.
3.	Thickness from 100' to 150' at 40' to 60' from surface.
4.	Thickness from 40' to 170' at 20' to 40' from surface.
5.	Thickness 2' 6" at 120' from surface.
6.	Thickness 139' 4" at 71', and 22' at 1,400'.
7.	Seven beds of brown coal aggregating 808'.
8.	21' at 368'.
9.	193' at 45' from surface.
10.	125' aggregate at 40' to 195' from surface.
11.	12' at 250', and 6' at 391'.
12.	2' at 252', 4' at 308', 16' at 380', 10' at 405'.

TROISIÈME SÉANCE.

Séance consacrée à la discussion sur communications diverses.

8 août.

La séance est ouverte à 10 h. du matin sous la présidence de M. F. D. ADAMS, MM. T. C. DENIS et J. A. BANCROFT agissant comme secrétaires.

Les travaux suivants sont présentés:

H. KEIDEL, *Über das Alter, die Verbreitung und die gegenseitigen Beziehung der verschiedenen tektonischen Structuren in den argentinischen Gebirgen* (page 671).

Une discussion s'engage au sujet de ce travail et MM. STEINMANN et ADAMS y prennent part.[1]

G. A. F. MOLENGRAAFF, *Folded mountain chains, overthrust sheets and block-faulted mountains in the East Indian archipelago* (page 689).

Le sujet de cette communication est discuté par MM. WELTER, VAUGHAN et STEINMANN.

L. E. GENTIL, *La géologie du Maroc* (page 703).

M. H. F. REID fait quelques observations sur le sujet de cette étude.

La séance est levée.

QUATRIÈME SÉANCE.

Séance consacrée à la discussion sur le sujet No. 7, Les caractéristiques physiques des mers paléozoiques et les particularités de leur faune considérées au point de vue de la portée du retour des mers dans l'établissement des systèmes géologiques.

9 août.

La séance est ouverte à 10 h. du matin sous la présidence de M. G. STEINMANN, MM. GOLDMAN et HARTNAGEL faisant fonction de secrétaires.

Il est convenu que toute discussion ne sera permise qu'après lecture de tous les ouvrages.

Les communications suivantes sont présentées:

T. C. CHAMBERLIN, *The shelf-seas of the Paleozoic and their relation to diastrophism and time divisions* (page 539).

G. STEINMANN, *Die paläozoischen Meere in Südamerika.*

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[1] On trouvera un résumé de la discussion aux pages qui suivent le travail dont il est question.

C. SCHUCHERT, *The delimitation of the geologic periods illustrated by the paleogeography of North America* (page 555).

F. FRECH, *The Palaeozoics of the Bagdad railway.*

O. HOLTEDAHL, *On the Old Red Sandstone series of northwestern Spitzbergen* (page 707).

Après la lecture de l'ouvrage de M. HOLTEDAHL, la séance est interrompue pour le lunch et reprise à 2.30 h. à titre de séance de section 2, et les articles suivants sont lus:

E. O. ULRICH, *The Ordovician-Silurian boundary* (page 593).

R. T. CHAMBERLIN, *Periodicity of Paleozoic orogenic movements.*

Dans la discussion qui suit on entend MM. J. M. CLARKE, STEINMANN, ...OEL, H. S. WILLIAMS, WIELAND et ULRICH.

La séance est levée à 5.05 de l'après-midi.

CINQUIÈME SÉANCE.

Séance consacrée à la réception de propositions et rapports des commissions internationales.

11 août.

La séance est ouverte à 10.15 h. du matin sous la présidence de M F. D. ADAMS, le Secrétaire général, M. R. W. BROCK, faisant fonction de secrétaire.

Le rapport de la Commission du prix Spendiaroff (page 127) est lu et approuvé.

Le rapport de la Commission sur les ressources mondiales en minerais de fer (page 128) est lu et approuvé.

Le rapport du Comité exécutif du Douzième Congrès géologique international, sur la proposition de Dr. HOBBS relative à une coopération internationale pour l'étude des systèmes de fracture de l'écorce terrestre (page 152) est alors lu et approuvé.

Les rapports du Conseil acceptant l'invitation de la Belgique de tenir la XIIIe Session du Congrès géologique international et fixant l'année 1917 comme la date du Congrès sont lus et approuvés.

Le Président lit les communications de la République Argentine et de l'Espagne invitant le Congrès pour une des sessions suivantes (page 158).

La séance est levée

Après l'expédition des affaires du jour, les membres présents se forment en section spéciale sous le présidence de M. SEDERHOLM pour entendre la lecture des études qui n'ont pas pu être atteintes aux séances antérieures.

M. L. MILCH fait une démonstration de la plasticité du sel gemme à de hautes températures (page 891) et fournit aux membres présents l'occasion d'exécuter eux mêmes des expériences. Pour commémorer l'occasion, une plaque est remise au Président portant l'inscription suivante faite en cristaux courbés de sel gemme:—

Congrès géologique international, 1913.
NaCl.

M. P. D. QUENSEL lit une communication sur *A new area of nepheline rocks in Sweden*. Une discussion s'engage à laquelle prennent part MM. KEMP, SEDERHOLM, CONNOR et ADAMS et où il est fait allusion à la similitude entre les roches décrites par M. QUENSEL et les roches de syénite qu'on a vues au cours de l'Excursion A 2 avant le Congrès.

Après la discussion, la séance de section spéciale fut ajournée à l'après-midi

SIXIÈME SÉANCE.

Séance consacrée à la discussion sur le sujet No. 4. L'origine et l'importance des sediments precambriens.

13 août.

La séance s'ouvre à 10 h. du matin sous la présidence de M. P. M. TERMIER, MM. W. H. COLLINS et M. E. WILSON agissant comme secrétaires.

Les communications suivantes sont présentées:

G. A. J. COLE, *Illustrations of the formation of composite gneisses and amphibolites in northwest Ireland*, illustré de projections lumineuses (page 311).

M. ADAMS au nom de l'assemblée félicite l'auteur de la façon claire dont il a établi l'analogie des gneiss de l'Irelande avec ceux du Canada.

J. J. SEDERHOLM, *Different types of Pre-Cambrian unconformities* (page 313).

JOHN HORNE, *The Pre-Cambrian sedimentaries between the Moine thrust and the eastern border of the Scottish Highlands.*

Le Président déclare qu'il est absolument de l'avis de M. HORNE.

J. J. SEDERHOLM, *Regional granitization (or anatexis)*, illustré de projections lumineuses (page 319).

Dans la discussion qui suit on entend MM. LAWSON, COLE et SEDERHOLM.

W. S. BAYLEY, *The Pre-Cambrian sedimentary rocks in the highlands of New Jersey* (page 325).

C. K. LEITH, *Relations of the plane of unconformity at the base of the Cambrian to terrestrial deposition in late Pre-Cambrian time* (page 335).

La question est discutée par MM. LANE, SEDERHOLM et HORNE et la séance est levée.

SEPTIÈME SÉANCE.

Séance consacrée à la discussion sur le sujet No. 5: Les subdivisions, la corrélation et la terminologie du precambrien.

13 août.

La séance s'ouvre à 2.30 h. de l'après-midi, sous la présidence de M. A. Strahan, M. J. A. Bancroft faisant fonction de secrétaire.

Les communications suivantes sont lues:

A. Strahan, *The subdivisions and correlation of the Pre-Cambrian rocks of the British Isles* (page 339).

A. C. Lawson, *A standard scale for the Pre-Cambrian rocks of North America* (page 349).

Sir T. H. Holland, *The Archæan and Purana groups of peninsular India* (page 371).

J. J. Sederholm, *Some proposals concerning the terminology of the Pre-Cambrian* (page 381).

A. P. Coleman, *The Sudbury series and its bearing on Pre-Cambrian classification* (page 387).

M. Coleman fait un résumé de son travail.

W. H. Collins, *A classification of the Pre-Cambrian rocks in the region east of Lake Superior* (page 399).

En l'absence de M. Collins, on lit seulement le titre de son ouvrage.

C. K. Leith, *Pre-Cambrian correlation from the Lake Superior standpoint* (page 409).

J. Deprat, *The geology of Indo-China and Honan.*

En l'absence de M. Deprat, le titre seulement de sa communication est donné.

A. Lacroix, *Les roches alcalines de Madagascar comparées à celles des montagnes montérégiennes*, et
Les ressources minéralogiques de Madagascar.

En l'absence de M. Lacroix, on se contente de donner le titre de ses deux articles.

Le sujet général, les subdivisions, la corrélation et la terminologie du précambrien, donne lieu à une discussion animée à laquelle prennent part MM. Lane, Lawson, Leith, Sederholm, Coleman, Barlow, Cole, Horne, Chamberlin, Fermor et Sir Thomas Holland.

Le président résume la discussion et fait ressortir en quelques mots l'importance des opinions émises, et la séance est levée.

HUITIÈME SÉANCE.

Séance de clôture.

14 août.

La séance est ouverte à 10 h. du matin, sous la présidence de M. F. D. ADAMS, le Secrétaire général, M. R. W. BROCK, faisant fonction de secrétaire.

En ouvrant la séance, M. ADAMS fait remarquer que c'est la dernière réunion du Congrès. Il remercie les membres de leur assiduité et de leur intérêt.

M. F. FRECH lit ensuite les rapports des Commissions sur la Palaeontologia Universalis (page 132) et sur la publication d'un lexique de stratigraphie (page 132). Ces rapports sont approuvés.

M. E. DE MARGERIE lit ensuite le rapport de la Commission internationale des glaciers (page 144) lequel est approuvé.

Au sujet de la Commission sur le degré géothermique, M. ADAMS lit une lettre de M. G. F. BECKER lui faisant parvenir une communication de la part de M. F. HALET à l'effet que la Commission n'avait pas de rapport formel à faire, mais qu'un rapport sera déposé à la treizième session.

Le Secrétaire général lit la proposition de M. J. J. SEDERHOLM invitant les services géologiques à une coopération plus active dans l'étude des zones contiguës du précambrien (page 157). Approuvé.

Il lit ensuite les propositions suivantes déjà approuvées par le Conseil en sa séance du 14 août, et toutes les deux sont acceptées:—

(1) Proposition à l'effet de nommer une commission se composant du Secrétaire général du Comité exécutif du prochain Congrès et de deux anciens secrétaires généraux désignés par celui-ci, pour fixer le format de la monographie qui devra être publiée par le Congrès, le nombre de pages réservés à chaque pays et les dates auxquelles les manuscrits devront être remis. Cette commission doit aussi avoir le droit de juger si les cartes et illustrations fournies par les auteurs des articles s'adaptent bien à la reproduction (page 157.)

(2) Proposition qu'un petit comité international soit nommé, composé de pas plus de huit personnes ayant pris une part active aux travaux des Comités exécutifs des sessions précédentes du Congrès, pour étudier la question d'établir une constitution et des règlements permanents, et pour soumettre, si c'est possible, une proposition à cet effet à la prochaine session du Congrès (page 157.)

Le président lit le rapport de la Commission de la carte géologique internationale (page 141) lequel est approuvé.

M. G. O. SMITH propose le vote de remerciements suivant, lequel est adopté à l'unanimité.

RESOLUTION OF THANKS.

"The Twelfth International Geological Congress desires to express its deep sense of gratitude to all who have contributed in any way to the success of the Congress and to the comfort and pleasure of the delegates and members. It desires to thank Field Marshal, His Royal Highness the DUKE OF CON- NAUGHT for graciously extending his patronage; to thank the Government of Canada for its very generous support, not only in contributing substantial financial assistance, but in placing at the service of the Congress so many of its officials and, generally, in aiding the Congress by every possible means; to thank the Governments of Ontario, Quebec, British Columbia and Nova Scotia for similar support; to thank the Governors and President of the University of Toronto for placing at the disposal of the Congress the splendid equipment and buildings of the university; and in this connection, it de- sires to especially mention Mr. GRAHAM CAMPBELL, Superintendent of Build- ings, and Mr. CHRISTIE, who by their excellent arrangements have contributed so much to the comfort and convenience of the members of the Congress; to thank the colleges that have opened their residences and dining halls for the use of the Congress; and to thank all persons official, professional and non-professional, throughout the length and breadth of Canada, who by their labours, contributions and hospitality have made the session and ex- cursions of the Congress such noteworthy and memorable events in the his- tory of the Congress.

The notable success of the Twelfth International Geological Congress has been made possible by the wise endeavours and indefatigable industry of its Executive Committee. This Congress therefore extends its congratu- lations and expresses its gratitude to the members of the Committee, who by their efficiency have so well represented their nation and our science. Special congratulations are due the officers of the Congress, President ADAMS and General Secretary BROCK, the one so honourably representing Canadian universities and the other so ably leading the Dominion Geological Survey, the geologists of which have contributed so effectively to the presentation of Canada's great natural resources and interesting geologic phenomena to the members of this Congress."

Le Président très ému à la suite de ce vote de remerciements fait les plus grands éloges de l'active coopération des membres et délégués étrangers.

M. RENIER exprime tous ses remerciements au Congrès d'avoir bien voulu accepter l'invitation de la Belgique à tenir sa treizième session dans ce pays et espère que cette session à venir pourra compter sur la coopération de tous les membres. Il termine en souhaitant de retrouver tous les membres présents à Bruxelles en 1917.

Le Secrétaire général, M. BROCK, dit combien il regrette que son travail l'ait empêché de connaître un plus grand nombre de membres. Il les remercie d'avoir si bien contribué par leur présence au magnifique succès du Congrès, et se montre reconnaissant de leur indulgence et de leur patience lorsque l'accomplissement de certains détails du programme a pu quelquefois laisser à désirer. Il espère avoir l'occasion de faire plus ample connaissance avec chacun des members lors du prochain Congrès.

La séance est levée.

SÉANCES DE SECTIONS.

Section 1, Géologie précambrienne et économique, Pétrologie, Minéralogie, etc.

PREMIÈRE SÉANCE.

Sujet No. 2: Différenciation dans les magmas ignés.

8 août.

La séance s'ouvre à 2.40 h. de l'après-midi, sous la présidence de M. H. Bäckström, M. P. D. Quensel agissant comme secrétaire.

Le président annonce que les discussions ne seront permises qu'après la lecture de toutes les communications.

Les articles suivants sont lus:—

R. A. Daly, *Sills and laccoliths illustrating petrogenesis* (page 189).

A. Harker, *Fractional crystallization the prime factor in the differentiation of rock magmas* (page 205).

J. P. Iddings, *Some examples of magmatic differentiation and their bearing on the problem of petrographical provinces* (page 209).

H. S. Washington, *The volcanic cycles in Sardinia* (page 229).

W. H. Hobbs, *Variations in composition of pelitic sediments in relation to magmatic differentiation* (page 241).

Une discussion s'engage sur les opinions émises dans ces articles au sujet de la différenciation magmatique, et l'on entend les membres suivants:— A. C. Lane, F. Loewinson-Lessing, W. Cross, J. W. Evans, L. Pirsson, G. F. Becker, J. P. Iddings, Th. Dahlblom, A. Bergeat, N. L. Bowen, B. Hobson, W. S. Bayley et H. Bäckström.

La séance est levée.

DEUXIÈME SÉANCE.

Communications diverses: Géologie économique et chimique.

9 août.

La séance s'ouvre à 2.45 h. de l'après-midi sous la présidence de M. H. Miers, MM. H. Backlund et A. A. Cole agissant comme secrétaires.

Les communications suivantes sont présentées:

J. Samojloff, *Ergebnisse der geologischen Untersuchungen über die Phosphoritlagerstätten Russlands* (page 843).

C. N. Gould, *The occurrence of petroleum and natural gas in the Mid-continent field* (page 861).

Une discussion suit, à laquelle prennent part MM. D'INVILLIERS, CADMAN et l'auteur de l'article.

J. DE SZÁDECZKY, *Natural gas in Transylvania* (page 869).

G. F. KUNZ, *The geological occurrence of precious stones on the American continent.*

Le sujet de cette étude est discuté par MM. CADMAN et HOLMAN.

L. MILCH, *Über die Plastizität des Steinsalzes und ihre Abhängigkeit von der Temperatur* (page 891).

M. MILCH a donné une démonstration pratique de la plasticité du sel gemme à la séance générale du 11 août.

La séance est levée.

TROISIÈME SÉANCE.

Sujet No. 3: L'influence de la profondeur sur la nature des gisements métallifères.

11 août.

La séance est ouverte à 2.30 h. sous la présidence de M. G. O. SMITH, M. R. P. D. GRAHAM agissant comme secrétaire.

Le président annonce qu'il a été décidé de n'accorder que dix minutes pour la lecture de chaque étude afin que l'on ait tout le temps voulu pour la discussion.

Les communications suivantes sont présentées:—

J. F. KEMP, *The influence of depth on the character of metalliferous deposits* (page 253).

MM. TABER, BECKER, RANSOME, LINDGREN, LAWSON et LANE prennent part à la discussion qui suit.

W. H. EMMONS, *The mineral composition of primary ore as a factor determining the vertical range of metals deposited by secondary processes* (page 261)

La question est discutée par MM. KEMP, READ, UDDEN, H. V. WINCHELL et LAWSON et sur proposition de M. KRUSCH, la suite de la discussion est remise jusqu'après la lecture de l'article de M. KRUSCH.

L. L. FERMOR, *The formation in depth of oxidized ores and secondary limestone* (page 271).

M. PAIGE fait quelques remarques sur le sujet.

P. J. KRUSCH, *Primäre und sekundäre Erze unter besonderer Berücksichtigung der "Gel" und der schwermetallreichen Erze* (page 275).

Une discussion suit à laquelle prennent part MM. H. V. WINCHELL, LANE, LINDGREN, KITSON, BAKER, MAIER, EMMONS et l'auteur de l'article.

P. R. FANNING, *A contribution to the metallogeny of the Philippine Islands* (page 287).

Cette conférence donne lieu à une courte discussion générale après quoi la séance est levée.

Section 2, Paléontologie et Stratigraphie.

PREMIÈRE SÉANCE.

Communications diverses.

11 août.

La séance s'ouvre à 2.30 h. de l'après-midi, sous la présidence de M. L. Baldacci, M. J. A. Bancroft agissant comme secrétaire.

Les communications suivantes sont présentées:—

Pierre Pruvost, *La faune continentale du terrain houiller du nord de la France; son utilisation stratigraphique* (page 925).

E. T. Mellor, *On the mode of deposition of the auriferous conglomerates of the Witwatersrand* (page 895).

M. Cole fait remarquer que les idées développées par M. Mellor sont d'autant plus intéressantes que l'on attribue maintenant une origine terrestre au "Old Red Sandstone" de l'Angleterre.

C. R. Keyes, *Certain features of eolic gradation* (page 941).

J. T. B. Ives, *Geological cartography.* Illustrée au moyen de cartes du type dont il est question dans l'article.

Après la conférence de M. Ives, la séance est levée.

Section 3, Géologie glaciaire et Physiographie.

PREMIÈRE SÉANCE.

Sujet No. 6: Dans quelle mesure l'époque glaciaire a-t-elle été interrompue par des périodes interglaciaires?

8 août.

La séance est ouverte à 2.30 h. de l'après-midi, sous la présidence de M. T. C. Chamberlin, avec MM. F. W. DeWolf, W. A. Johnston et M. I. Goldman en qualité de secrétaires. A la demande du président il est convenu qu'on limitera à 20 minutes le temps accordé pour la lecture de chaque article et que la discussion ne sera permis qu'après cette lecture complète.

Les communications suivantes sont présentées:

G. W. Lamplugh, *The Interglacial problem in the British Isles* (page 427).

Vu l'absence de l'auteur l'article est lu par M. Strahan.

A. P. Coleman, *An estimate of post-Glacial and inter-Glacial time in North America* (page 435).

M. Coleman donne seulement un résumé de son ouvrage.

G. F. Wright, *Recent date of the attenuated glacial border in Pennsylvania* (page 451).

WARREN UPHAM, *The Sangamon inter-Glacial stage in Minnesota and westward* (page 155).

T. F. W. WOLFF, *Glazial und Interglazial in Norddeutschland* (page 167).

Le titre de l'ouvrage seulement est lu et M. WOLFF fait sur le sujet une courte conférence illustrée de projections lumineuses.

W. C. ALDEN, *Early Pleistocene glaciation in the Rocky mountains of Glacier National Park, Montana* (page 179).

En l'absence de l'auteur on lit seulement le titre de l'article et le président en donne un résumé.

Ces communications donnent lieu à une discussion générale à laquelle prennent part MM. KÜMMEL, FRECH, COLEMAN, KAY, BAKER, LEVERETT, G. F. WRIGHT, T. F. W. WOLFF, UPHAM, TAYLOR, LEES et T. C. CHAMBERLIN.

La séance est levée à 5.45 h.

SECONDE SÉANCE.

Sujet No. 6: Dans quelle mesure l'époque glaciaire a-t-elle été interrompue par des périodes interglaciaries (suite).

13 août.

La séance est ouverte à 10 h. du matin, sous la présidence de M. W. F. HUME; MM. W. H. MCNAIRN et A. L. PARSONS agissant comme secrétaires.

Les communications suivantes sont présentées:

N. O. HOLST, *Le commencement et la fin de la période glaciaire* (page 185).

En l'absence de l'auteur, M. T. F. W. WOLFF donne lecture d'un résumé de cette étude en allemand.

H. L. FAIRCHILD, *New York state under the Labradorean ice-sheet.*

Le titre de l'ouvrage seulement est lu et M. FAIRCHILD prononce sur ce sujet un discours illustré d'une série nombreuse de cartes faisant voir les phases successives intervenues dans le développement de la topographie de l'état de New-York durant l'époque glaciaire.

Ce discours donne lieu à une discussion à laquelle prennent part MM. H. V. WINCHELL, G. F. WRIGHT et l'auteur de l'article.

WARREN UPHAM, *Fields of outflow of the North American ice-sheet* (page 515).

M. EVANS fait quelques observations sur cet article; il est d'avis que M. UPHAM attribue à la nappe de glace une marche trop rapide.

J. B. TYRRELL, *The Patrician glacier south of Hudson bay* (page 523).

La conférence est suivie de quelques remarques de la part de MM. LEVERETT et FAIRCHILD.

La séance est levée à midi.

Section Speciale.

PREMIÈRE SÉANCE.

Tectonique.

9 août.

La séance est ouverte à 10.45 h. du matin sous la présidence de M. E. DE MARGERIE, M. T. C. DENIS, agissant comme secrétaire.

Les communications suivantes sont présentées:—

L. E. DAHLBLOM. *The angle of shear* (page 773).

On lit seulement le titre de l'ouvrage et l'auteur fait un bref discours sur ce sujet.

ERNEST HOWE. *Landslides and the sinking of ground above mines* (page 775).

D. MCDONALD. *Excavation deformations* (page 779).

En l'absence de M. MCDONALD on lit seulement le titre de l'ouvrage et M. BECKER en donne un aperçu.

E. O. HOVEY. *Note on landslides* (page 793).

La séance est levée.

SECONDE SÉANCE.

Séance consacrée à la lecture des études qui n'ont pas pu être présentées aux séances antérieures, (continuation de la séance du matin).

11 août.

La séance est ouverte à 2.20 h. de l'après-midi sous la présidence de M. J. J. SEDERHOLM, M. P. D. QUENSEL agissant comme secrétaire.

Les communications suivantes sont présentées:—

BAILEY WILLIS. *Physiography of the Cordillera de los Andes* (page 733).

H. KEIDEL. *Über den Anteil der quartären Klimaschwankungen und der Gestaltung der Oberfläche des Gebirges im Trockengebiet der mittleren und nördlichen argentinischen Anden* (page 757).

Ces deux ouvrages donnent lieu à une discussion à laquelle prennent part MM. QUENSEL, STEINMANN, EVANS, KEIDEL, PAULCKE, WILLIS et FANNING.

M. S. MASO et W. D. SMITH. *The relation of seismic disturbances in the Philippines to geologic structure* (page 807).

L'article est présenté par M. FANNING qui en donne un bref aperçu.

W. E. PRATT. *Petroleum on Bondoc peninsula, Tayabas province, Philippines* (page 901).

Cette communication est également présentée par M. FANNING et on en lit seulement le titre.

W. PAULCKE. *Über tektonische Experimente* (page 835).

M. CADELL fait quelques observations sur ce sujet.

La séance est levée.

COMMISSIONS DU CONGRÈS.

COMMISSION DU PRIX SPENDIAROFF.

Le Prix international Spendiaroff a été institué en 1897 quand M. SPENDIAROFF de St.-Pétersbourg a offert en mémoire de son fils M. LEONIDE SPENDIAROFF une somme de 4,000 roubles qu'il a placée au crédit du Congrès géologique international pour instituer un prix qui serait accordé à chaque session du Congrès, aux conditions que fixerait le Conseil.

A la session suivante, en 1900, les règlements suivants ont été adoptées pour l'attribution du prix:—

Art. 1.—L'attribution du prix par le Congrès doit être fondée sur les conclusions d'un jury, élu, sur la proposition du Conseil, à chaque session en vue du prix à décerner dans la session suivante. Le nombre des membres de ce jury est déterminé, chaque fois, par le Congrès.

Art. 2.—Les ouvrages présentés pour le concours doivent être envoyés au Secrétaire général du dernier Congrès, au nombre de deux exemplaires au moins. L'envoi sera fait au plus tard une année avant la session suivante.

Art. 3.—Le droit de priorité pour obtenir le prix appartient aux œuvres traitant les sujets proposés par le Congrès.

Art. 4.—Si les œuvres de cette catégorie ne sont pas jugées dignes du prix, le Congrès peut, sur la proposition du jury, choisir parmi les ouvrages publiés pendant les cinq années précédentes ceux qui seront reconnus les plus importants par leur portée scientifique.

En 1903, le Conseil a établi un roulement dans l'ordre des sujets donnés, savoir:—

1. Pétrographie.
2. Géologie générale.
3. Paléontologie.

Depuis l'établissement du prix, il a été accordé comme suit:—

1900.—M. A. KARPINSKY (par vote du Conseil).

1903.—M. W. C. BRÖGGER, pour son ouvrage pétrographique.

1906.—M. TH. TSCHERNYSCHEW, pour son travail *Die oberkarbonischen Brachiopoden des Ural und des Timan.*

1910.—M. J. M. CLARKE, pour son travail *Early Devonic History of New York and Eastern North America.*

1913.—M. ÉMILE ARGAND, pour son mémoire *Les nappes de recouvrement des Alpes occidentales.*

RAPPORT DE LA COMMISSION DU PRIX SPENDIAROFF.

Présenté par G. STEINMANN,
remplaçant le Président de la Commission, M. A. G. HÖGBOM.

La Commission représentée par quatre membres: MM. G. O. SMITH, G. STEINMANN, P. M. TERMIER, TH. TSCHERNYSCHEW, à la séance du 8 août, 9h. 30m. du matin propose d'accorder le prix à M. ÉMILE ARGAND, pour son mémoire: *Les nappes de recouvrement des Alpes occidentales*, 1911.

Ce travail ne correspond pas exactement aux conditions du thème approuvé au Congrès de Stockholm: "Étude critique des bases de la théorie des grands charriages," parcequ' il ne contient pas une critique de la théorie; c'est plutôt une application de la théorie sur une vaste région des Alpes occidentales, équivalant à une critique en ce sens, qu'elle montre, par une étude approfondie, que c'est la théorie des grands charriages, qui explique le mieux les phénomènes extrêmement compliqués, qui s'observent à travers la chaîne alpine jusqu'à la région des racines en état de metamorphisme régional.

La majorité de la Commission était d'avis, que la synthèse magistrale des Alpes contenue dans le 3e volume de *Das Antlitz der Erde*, par M. EDOUARD SUESS, digne de la plus haute considération, doit être considérée comme hors de concours au prix Spendiaroff.

La Commission soumet à l'approbation le thème suivant pour le prochain concours:

"Le meilleur travail pétrographique apportant de nouvelles lumières sur les problèmes généraux de la science."

Adopté à la séance du Conseil, le 9 août et à la séance générale, le 11 août.

MEMBRES DE LA COMMISSION DU PRIX SPENDIAROFF.

(Elus à la séance générale du 11 août 1913.)

M. ADAMS, Président: MM. BÄCKSTRÖM, BECKE, BRÖGGER, CROSS, HARKER, KARPINSKY, LACROIX, F. LOEWINSON-LESSING, MILCH, MOLENGRAAFF, TEALL.

COMMISSION DES RESSOURCES MONDIALES EN MINERAIS DE FER.

Constituée au XIe Congrès, Stockholm, 1910.

RAPPORT DE LA COMMISSION DES RESSOURCES MONDIALES EN MINERAIS DE FER.

par J. P. KRUSCH,
en remplacement de F. BEYSCHLAG, Président de la Commission.

Lors du XIe Congrès géologique international, dans les enquêtes faites par les géologues des différents pays pour la préparation de l'ouvrage

The Iron Ore Resources of the World, aucune méthode uniforme n'a été suivie.

Quoiqu'au point de vue des renseignements, le résultat de ces recherches soit très précieux, il n'est possible de faire aucune comparaison entre les ressources des différents pays.

Non seulement est-il nécessaire de connaître le tonnage des minerais et leur concentration, mais aussi faut-il considérer d'autres facteurs, tels que: le mode de gisement (la structure), les frais d'exploitation, les possibilités du marché et les frais de transport. C'est pourquoi le Congrès géologique international de Stockholm a résolu de former une commission internationale qui aurait pour but d'étendre les recherches et de réétudier cette question d'après une méthode uniforme au point de vue économique.

La commission devrait se composer d'un géologue et d'un représentant de l'industrie sidérurgique pour chacun des six pays les plus importants dans cette industrie: l'Angleterre, la France, les États-Unis, la Russie, la Suède et l'Allemagne.

Le représentant de l'Allemagne a été chargé des travaux préliminaires. Dans cette étude, que nous avons faite pour établir une base à notre nouveau système, nous avons constaté que tous les chiffres donnés par le volume du XI^{e} Congrès étaient exacts, mais qu'il était impossible d'arriver à une bonne fin si on négligeait les facteurs déjà nommés.

Il s'agissait de déterminer une méthode pour arriver à ces facteurs économiques. On se proposait d'adresser, en premier lieu, une feuille d'enquête aux collaborateurs de la *monographie* qui devaient donner les renseignements nécessaires à l'évaluation des gisements métallifères de leur pays. Cette feuille ayant été établie, ce qui pris un temps considérable, elle a été soumise aux représentants de l'industrie sidérurgique dans le but de connaître leurs idées concernant l'exactitude de ces données. Ces représentants déclarèrent qu'il était peu pratique de faire les études demandées dans le questionnaire, car pour répondre avec exactitude à la majeure partie des questions, il faudrait un temps trop considérable, et qu'à part cela, même avec la plus grande précision, il est impossible de saisir tous les facteurs qui sont importants dans l'évaluation des gisements. Le résultat des conférences avec les représentants a conduit à l'établissement d'un tableau divisé en trois groupes:—

1er groupe.—Minerais de fer actuellement exploitables sans difficulté.

2^{e} groupe.—Minerais de fer dont l'exploitation dépend de certaines conditions faciles à réaliser.

3^{e} groupe.—Minerais de fer dont l'exploitation dépend de plusieurs conditions moins faciles à réaliser.

Les ressources des deux premiers groupes sont à établir en chiffres; pour le troisième il suffit de mentionner si les ressources sont faibles, moyennes ou grandes.

Pour le 2^{e} groupe, on a établi les tableaux suivants qui ont trait non seulement au fer, mais aussi au manganèse, au phosphore, au silicium, à l'alumine, au carbonate de chaux, etc.

GROUPE 1.—MINERAIS DE FER EXPLOITABLES SANS DIFFICULTÉ.

	Minerais de fer à teneur basse.	Minerais de fer à teneur moyenne.	Minerais de fer à teneur haute.
Teneur en fer.	32%	32-45%	45-60%
Acide silicique—alumine —chaux.	10-15%	15-20%	20-20%
Phosphore { Minerais Thomas.[1]	0.7%	0.8%	0.9-1%
Phosphore { Minerais Bessemer.[1]	0.03%	0.04%	0.05%
Frais d'exploitation.	2.5-3M.	3-6M.	6-10M.
Frais de transport.	0.5-1.5M.	1.5-3M	3-6M.

Déduction faite de 1.5%, il faut ajouter le double de la teneur en manganèse à la teneur en fer pour les minerais contenant du manganèse.

Dans les minerais de fer riches en manganèse, à mesure que la teneur en manganèse baisse, le phosphore baisse aussi. La teneur en titane jusqu'à 3% ne change pas essentiellement la valeur d'un minerai de fer.

GROUPE 2.—MINERAIS DE FER DONT L'EXPLOITATION DEPEND DE CERTAINES CONDITIONS FACILES A RÉSOUDRE.

	Minerais de fer à teneur basse.	Minerais de fer à teneur moyenne.	Minerais de fer à teneur haute.
Teneur en fer.	25%	25-45%	45-60%
Acide silicique—alumine —chaux.	10-15%	15-25%	25-30%
Phosphore { Minerais Thomas.[1]	0.5%	0.6-0.8%	0.9-1%
Phosphore { Minerais Bessemer.[1]	0.025%	0.03-0.04%	0.04-0.05%
Frais d'exploitation.	3-4M.	4-8M.	8-12M.
Frais de transport.	1.5-3M.	3-5M.	5-8M.

Tous les autres minerais de fer à composition moins riche et à frais d'exploitation et de transport plus élevés sont à placer dans le troisième groupe. En considérant, par exemple, la valeur d'un gisement, il faut toujours prendre comme base la valeur totale indiquée dans chaque tableau. Ainsi, un gisement dont les frais d'exploitation sont moins élevés figure dans le tableau come ayant plus de valeur qu'un autre où la teneur en fer serait plus élevée.

[1] Pour le calcul de la teneur en phosphore, on a pris comme base une teneur maximum de 2% pour la fonte Thomas et une teneur maximum de 0.08%-0.1% pour la fonte Bessemer, vu que la teneur totale du phosphore dans les minerais reste dans les fontes sans perte appréciable.

Ces tableaux ont été établis par les experts de l'industrie sidérurgique. Pour hâter les travaux, les membres du Comité ont fait des voyages en Autriche, en Hongrie, en Suède et en France. Il leur incombe maintenant d'examiner ces tableaux et de les prendre comme base à une nouvelle évaluation des ressources en minerais de fer au point de vue économique. Il serait bon de confier ce travail aux collaborateurs à la monographie, avec l'aide des représentants de l'industrie sidérurgique.

Se sont offerts jusqu'à présent:—

MM. Louis, pour l'Angleterre; De Launay et Nicou, pour la France; Sjögren et Petersson, pour la Suède; Sedlaczek, pour l'Autriche-Hongrie; Kemp, pour les États-Unis; et Tschernyschew, pour la Russie.

On se propose de demander comme autres collaborateurs:

MM. Rogers et Molengraaff, pour l'Afrique du Sud; Brown, pour l'Australie du Sud; Maitland, pour l'Australie Occidentale; Kossmat, pour l'Autriche; Delmer, pour la Belgique; Katzer, pour la Bosnie et l'Herzégovine; Derby, pour le Brésil; Vankow, pour la Bulgarie; Haanel, pour le Canada; Read, pour la Chine; Cornet, pour le Congo; Hume, pour l'Egypte; Grabham, pour l'Egypte et le Soudan; Vidal, pour l'Espagne; Trüstedt, pour la Finlande; Nottmeyer, pour la Grèce, la Turquie et la Perse; Evans, pour la Guyane Anglaise; Lóczy et Papp, pour la Hongrie; Fermor, pour l'Inde Anglaise; Molengraaff, pour les Indes Néerlandaises; Aichino, pour l'Italie; Inouye, pour la Japon et la Corée; Dondelinger, pour le Luxembourg; Gentil, pour le Maroc; Ordoñez, pour le Mexique; Vogt, pour la Norvège; Pittman, pour la Nouvelle-Galles; Park, pour la Nouvelle Zélande; Comes, pour le Portugal; Koert, pour les Possessions Allemandes en Afrique; Evans, pour les Possessions Britanniques en Asie et en Afrique; Dunstan, pour le Queensland; Stappenbeck, pour la République Argentine; Mennell, pour la Rhodesia; Bogdanovitch, pour la Russie; Milojkovit[illegible], pour la Serbie; Schmidt, pour la Suisse; Twelvetrees, pour la Tasma[illegible]; Howley, pour Terre-Neuve; Davis, pour le Victoria.

Ces travaux de réédition devront être éxécutés dans les deux années qui vont suivre. Les collaborateurs et le XIIIe Congrès recevront les résultats. Le travail, d'après l'idée du XIe Congrès, sera soumis au Congrès international de Bergbau, Hüttenwesen, angewandte Mechanik und praktische Geologie pour le compléter.

Adopté à la séance du Conseil, et à la séance générale, le 11 août.

COMMISSIONS DE LA PALÆONTOLOGIA UNIVERSALIS ET DU LEXIQUE DE STRATIGRAPHIE.

(La Commission de la Palæontologia universalis a été consituée au VIIIe Congrès, Paris, 1900 et celle du lexique de stratigraphie au XIe Congrès, Stockholm, 1910.)

PROCÈS-VERBAL DE LA SÉANCE DES COMMISSIONS RÉUNIES DE PALÉONTOLOGIE ET STRATIGRAPHIE.

1. *Nomenclature paléozoologique.*

Suivant la proposition de M. F. Frech, la Commission décide à l'unanimité comme suit:

En conséquence de la révision des règles de la nomenclature zoologique, délibérée au Congrès international zoologique de Monaco, la Commission reprendra l'étude de la question, aussitôt que le Compte Rendu du dernier Congrès de Monaco sera publiés.

2. *Palæontologia universalis.*

La réédition des monographies classiques (par exemple, de Schlotheim et de Sowerby) n'est pas encore réalisée.

Selon une remarque de M. Th. Tschernyschew, l'Académie des sciences impériale de St.-Pétersbourg accordera probablement une subvention considérable pour cette œuvre très coûteuse. Le Congrès recommandera à la considération des académies et des sociétés scientifiques de tous les pays représentés de suivre cet exemple.

3. *Catalogus fossilium.*

M. F. Frech annonce la publication d'un *Catalogus fossilium*, qui comprendra, à l'exemple du *Nomenclator* de Brown un catalogue critique de tous les genres et de toutes les espèces paléontologiques et dont chaque fascicule comprend une ou plusieurs familles distinctes. Les deux premiers fascicules sont déjà parus. La continuation de cet ouvrage étant assurée par l'éditeur W. Junk, Berlin, sous la rédaction de F. Frech, Breslau et W. Jongmans, Leyden, le Congrès recommandera à ses membres une collaboration active. Il sera allouée une certaine rémunération aux contributeurs.

4. *Lexique stratigraphique international.*

En conséquence de précieux travaux préliminaires de M. L. Waagen, la Commission décide comme suit:

(a) Les noms stratigraphiques doivent être énumérés dans leur langue originale pour fixer le droit de priorité.

(b) On propose cinq volumes, un par continent, rédigés dans la langue dominante, et l'emploi exclusif de caractères latins.

(c) Une rémunération des collaborateurs est recommandée.

(d) Chaque volume paraît en fascicules régionaux, rédigés définitivement par des sous-commissions nationales.

(e) Les manuscrits sont demandés pour le 1er janvier 1917 par le rédacteur Dr. L. Waagen, Vienne, Rasumoffskygasse 23.

(f) Vu l'importance de l'œuvre, le XIIe Congrès géologique international demandera des subventions aux gouvernements et aux commissions géologiques nationales et promettra, le cas échéant, la publication des fascicules pour le prochain Congrès géologique international.

(g) Le prix d'un mark par feuille de 16 pages est considéré trop élevé et doit être réduit en proportion de la subvention.

5. *Élections.*

La Commission de paléontologie a élu comme membres nouveaux:

Pour l'Allemagne: M. Pompecki en remplacement de M. Koken, décédé; pour la Belgique: M. Dollo; pour le Canada: M. Brock.

Soumis au Congrès, ce 12 août 1913.

Th. Tschernyschew.

F. Frech.

C. De Stefani.

R. Lachmann, Secrétaire.

Adopté à la séance du Conseil, le 13 août et à la séance générale, le 14 août.

COMPOSITION DE LA COMMISSION DE LA PALÆONTOLOGIA UNIVERSALIS.

Président:

M. F. Frech, Breslau.

Secrétaire:

M. D. P. Œhlert, Laval.

J. Almera, Barcelona; F. A. Ba[illegible]r, Londres; E. Böse, Mexico; R. W. Brock, Ottawa; C. Burckhardt, Mexico; C. Canavari, Pise; P. Choffatt, Lisbonne; L. Dollo, Bruxelles; H. Douvillé, Paris; J. Fraipont, Liège; G. Holm, Stockholm; J. Kiær, Christiania; R. Lachmann, Breslau; P. de Loriol-Le Fort, Genève; A. Pavlov, Moscou; J. Pompecki, Göttingen; C. Schuchert, New Haven; E. van den Broeck, Bruxelles; C. D. Walcott, Washington; H. S. Williams, New Haven; A. S. Woodward, Londres.

RAPPORT DE LA COMMISSION DU LEXIQUE DE STRATIGRAPHIE.

Soumis par L. Waagen, Président de la Commission.

Herrn Direktor R. W. Brock, M.A., F.R.S.C.,
Generalsekretär des XII. Internationalen Geologenkongresses.
Ottawa.

Die von dem XI. Internationalen Geologenkongress zu Stockholm mit den Vorarbeiten für die Herausgabe eines Internationalen Stratigraphischen Lexikons betraute Kommission erlaubt sich dem verehrlichen XII. Internationalen Geologenkongress bezüglich dieses Werkes nachfolgendes Programm vorzulegen:

Zweck und *Nützlichkeit* eines internationalen stratigraphischen Lexikons braucht nicht erst dargelegt zu werden, da der Antrag zur Schaffung eines solchen Werkes bereits von dem XI. Kongresse angenommen wurde.

Was jedoch die *Art der Publikation* betrifft, so muss folgendes festgelegt werden: Das Lexikon ist in fünf Bänden herauszugeben: I. Europa, II. Amerika, III. Asien, IV. Afrika, V. Australien, Polynesien und Antarktis.

Die einzelnen stratigraphischen Namen erscheinen in alphabetischer Ordnung. Jeder Artikel muss ausser dem Schlagworte (stratigraphischen Namen) noch folgende Angaben enthalten: (a) Die Daten über seine erstmalige Aufstellung (Autor nebst genauer Literaturangabe), (b) Stellung des Schichtgliedes im Formationssystem und seine Umgrenzung, (c) eventuelle spätere Verschiebung oder Modifizierung des Begriffes mit Literaturnachweis, (d) gegenwärtige allgemeine Verwendung des Begriffes.

Alle Angaben sind möglichst konzis und objektiv zu halten.

Sprache: Die einzelnen Artikel können in deutscher, französischer, englischer oder italienischer Sprache abgefasst werden.

Organisation: Die vom XI. Internationalen Geologenkongress in Stockholm konstituierte Kommission übernimmt die Verpflichtung, die Mitarbeiter in der Weise zusammenzustellen, dass die Materie regional und sachlich verteilt wird. Die Manuskripte sind sodann bis zu einem bestimmten Termine (z.B. für den ersten Band "Europa" bis zum ersten Januar 1915) von den Autoren dem Herausgeber und Redakteur Herrn Dr. L. Waagen einzusenden, der die Drucklegung besorgt. Für jeden Erdteil, und somit für jeden Band, ist ein Subkomitee zu bilden, welches die Organisation und die Zusammenstellung der Mitarbeiter übernimmt.

Modalität der Drucklegung: An die Herren Mitarbeiter werden Drucksorten hinausgegeben werden, welche bei Abfassung der einzelnen Artikel zu verwenden sind, weil durch die Gleichförmigkeit derselben die Arbeit für den Herausgeber sehr erleichtert wird. Das Buch soll in Lexikonoktav erscheinen und sich in der Ausstattung an das "Lexique pétrographique" von Loewinson-Lessing anschliessen. Da die Drucklegung eines solchen Buches ziemlich lange Zeit in Anspruch nimmt, so könnte auch ein lieferungsweises Erscheinen vorgesehen werden, wobei jede Lieferung etwa sechs Druckbogen enthalten würde.

Finanzierung des Unternehmens. Diesbezüglich wird der XII. Internationale Geologenkongress in Toronto gebeten, diesem Unternehmen eine einmalige Subvention zuzuwenden, wie dies bei der *Palaeontologia Universalis* geschehen ist. Diese Subvention würde dazu dienen, die Auslagen für die nötigen Vorbereitungen zur Herausgabe zu decken und den Satz des ganzen Werkes einleiten zu können. Die weiteren Kosten würden, wie aus Erkundigungen bei Verlagshäusern hervorgeht, durch Subskriptionen aufgebracht werden können, wenn der verehrl kongress dem Unternehmen auch weiterhin seine moralische Unterstützung angedeihen lässt. Dabei ist ein Verkaufspreis von 1 M. per Druckbogen in Aussicht genommen.

Auf Grund einer Subvention würden dann sowohl die Subskriptionseinladungen als auch das Lexikon selbst die Insignien des "Geologorum conventus" tragen.

Wien, Berlin, Barcelona, Washington, Grenoble, London, Florenz, Lissabon, Petersburg, Lund
im März und April 1913.

L. WAAGEN,
als Präsident der Kommission.

W. BRANCA, J. ALMÉRA, C. D. WALCOTT, W. KILIAN, F. A. BATHER (mit Vorbehalt), C. DE STEFANI, P. CHOFFAT, A. KARPINSKY (mit Vorbehalt), A. HENNIG, als Mitglieder der Kommission.

In Ergänzung des Voranstehenden müssen hier zunächst die Vorbehalte der beiden oben unterzeichneten Herren F. A. BATHER und A. KARPINSKY angefügt werden:

F. A. BATHER schrieb mir unter dem 21 Februar:

"You propose to split the lexicon into five volumes according to a geographical arrangement. I venture to suggest that the work would be far more useful if it were arranged in simple alphabetical order. My reasons for this are as follows:

1. There are many terms that have an application, if not world-wide, at all events beyond the limits of a single continent. These would either have to be repeated in every volume or at least in more than one volume, or else the reader would have to search through various volumes before finding the term of which he was in quest.

2. There are certain terms, e.g., Bradfordian, which have been used in a different sense in different continents, and one advantage of such a stratigraphical lexicon would be to show that one of these uses has priority over the other, and that it alone should be accepted.

3. It is often the case that a worker in my position, who has to deal with specimens and with literature from all parts of the world, comes across a stratigraphical term unfamiliar to him and does not know exactly to which part of the world it especially refers; such a worker might then have to look through all the five volumes before he found the word of which he was in search.

All these three difficulties would be obviated by publishing the work in a single alphabetical series like any other lexicon."

"I can understand that for purposes of compilation, it may be well to take the various continents and countries, but when the various entries have been collected, it would be just as easy to combine them into a single series as to combine them into five series. Indeed, in some respects it would be easier, since in this way a certain amount of duplication would be avoided and various inconsistencies would be more easily seen."

"You say that the separate entries may be written in German, French, English or Italian. I am afraid that there will be some difficulty in this course. It may often be that a term will come in a different alphabetical position according to the language in which it is written, e.g., Silur, Silurian, Silurien, Silurie, Silurisch, or again Carbonic, Carboniferous and Carbon or Karbon. As regards the details given in separate entries the language certainly does not matter very much, because several of them could be expressed merely by numerals, or by the ordinary contractions. Moreover, in the case of stratigraphical units of small geographical extent, the names would naturally be given in the language of the country where that unit is developed, even if not one of the four languages mentioned above."

"Among the details to be given, I fancy you will find that headed '(C) Eventuelle spätere Verschiebung oder Modifizierung des Begriffes' will often occupy a large amount of space, and I think that some limit will have to be imposed on this."

"I am afraid that even at the price of one mark per printed sheet, the volume will be exceedingly expensive . . . ."

"So much for the letter addressed to Mr. BROCK, which I return to you signed as you request, but with the reservations made in this present letter."

"I gather further from your letter of February 19th that you wish me to obtain workers who will compile the entries for the British Isles. I think that one person will probably do the work very much better than two or more, and I hope that I may be able to get someone, but before proceeding it would be advisable to have some idea of the amount of the honorarium. . ."

Von Herrn A. KARPINSKY erhielt ich dagegen unter dem 11 März d.J. ein Schreiben mit folgenden Wünschen und Einwänden:

"(a) Die russische, vorläufig kleine Kommission (A. KARPINSKY, Dr. TSCHERNYSCHEW, Prof. ANDRUSSOW, Prof. NATSCHAJEW, Dr. ARCHANGELSKY, Prof. BORISSIAK und Prof. PAWLOW) glaubt, dass die stratigraphischen Namen in Sprache und Alphabet ihrer erstmaligen Aufstellung oder ihrer allgemeinen Landesverwendung im Lexikon Platz finden sollen:"

Beispiel 1.

Carbonifère, système (toutes les explications nécessaires).
Steinkohlenformation—v. Carbonifère, syst.
Steinkohlensystem—v. Carbonifère, syst.
Carbon—v. Carbonifère, syst.
Karbon—v. Carbonifère, syst.
Kamennougoljnaja sistema—(Nach von der Akademie der Wissenschaften in St. Petersburg und von The Royal Society of London angenommenen Transkription)—v. Carbonifère syst.

Beispiel 2.

A. FR. SCHMIDT (?Revision d. ostbaltischen silur. Trilobiten nebst geogn. Uebersicht d. ostbaltischen Silurgebiete. Abt. I. Mem. Acad. Sc. St. Petersburg, XXX., Nr. 1, 1881, S. 10.)

Division inférieure des sédiments cambro-siluriens de la Baltique orientale appartenant au Cambrien.

Beispiel 3.

Wesenberg'sche Schicht. FR. SCHMIDT, 1858. (Arch. f. Naturk. d. Liv. Esth. u. Kurlands, II, p. Mem. Ac. Sc. St. Petersburg, XXX, Nr. 1, 1881, S. 10).

Ostbaltische unter- (oder eo-) silurische Kalkschichten mit dünnen Mergellagern (*Chasmops Wesenbergensis* SCHM., *Orthis testudinaria* DALM., *Tentaculites anglicus* SALT., etc.) Unter Grenze: Jewsche Schichten obere: Lyckholms Schichten, mit welcher die Wesenbergschen Schichten dem Caradoc in England und dem Trentonkalk in Amerika entsprechen.

Beispiel 4.

E. (SCHMIDT)—Wesenbergsche Schichten.

"(b) Nach der Meinung einiger russischer Geologen soll jeder Band (d.h. alle Bestimmungen der stratigraphischen Namen) in einer einzigen bestimmten Sprache gedruckt werden, z.B. Europa-Band in französischer Sprache, Amerika-Band in englisch. Nach anderen Geologen sollen alle Bände in einer einzigen Sprache veröffentlicht werden."

"(c) Die einmalige Subvention des XII. Kongresses für die vorläufigen Arbeiten ist wünschenswert."

"(d) Was Anderes betrifft, ziehen wir vor: (1) dass die Arbeit von Fachgenossen gratis sein muss (wie bei *Palaeontologia Universalis, geolog. Karte von Europa*). (2) dass die folgenden Subventionen für die Vorbereitungen des Lexikon-Materials von der Regierung oder der geolog. Anstalt jedes Landes zugewendet sein müssen. (3) dass die Veröffentlichung jeden Bandes auf Kosten des Kongresses, welchem das Manuskript dieses Bandes in ganz fertigem Zustande vorgelegt werden kann, stattfinden kann, (z.B. als Anhang zum *Compte Rendu*, was für das LEWINSON'sche Lexikon der Pariser Kongress getan hat). Zweite und folgende Auflagen können an Verlagshäuser übergeben werden (nach einer Resolution des internationalen Kommission oder des Kongresses auf den Vorschlag der Kommission.)"

"(e) In Bezug auf die Subkomitee für jeden Band, welches Organisation und Zusammenstellung der Mitarbeiter übernimmt, glauben wir, das für Russland, wegen seiner Grösse und reichen russischen Literatur, eine besondere verantwortliche Subkommission mit vielen Mitgliedern und zahlreichen Mitarbeitern organisiert werden soll. Für das internationale Subkomitee des ersten Bandes kann man einen Repräsentanten der russischen Subkommission ernennen (Herrn Prof. ANDRUSSOW)."

"(f) Der bestimmte Termin (1. Januar 1915.) der Zusendung der Manuskripte, welcher weniger als 1½ Jahre für die vollständige Arbeit zieht ist nicht genügend. Es ist vielleicht vorsichtiger den Termin dieser Zusendung an den Herrn Hauptredakteur Dr. L. WAAGEN auf ein Halbjahr vor dem folgenden Kongress zu bestimmen (also Januar 1916)."

"(g) Es ist wünschenswert, jeden Band nicht in Lieferungen sondern als ein Buch zu veröffentlichen."

"(h) Ein Subskriptions- oder Verkaufspreis von 1 M. per Druckbogen finden wir zu hoch."

Den angeführten Vorbehalten von F. A. Bather, (England) und A. Karpinsky (Russland) müssen noch die folgenden mit geäusserten Wünsche hinzugefügt werden:

So spricht W. Branca (Berlin) den Wunsch aus, ein Honorar für die Herren Mitarbeiter festzustellen, während mir von anderer Seite, ich nenne nur die United States Geological Survey, zwar die Mitarbeit in zuvorkommendster Weise zugesagt wurde, wogegen ausdrücklich aufmerksam gemacht wird dass eine finanzielle Beihilfe bei der geplanten Form des Unternehmens nicht möglich wäre.

Es obliegt nunmehr dem Unterzeichneten zu diesen Bemerkungen und Einwänden Stellung zu nehmen. Ich wende mich zunächst den Vorschlägen F. A. Bather's zu:

Die Entscheidung darüber, ob das geplante Lexikon in fünf, nach geographischen Gesichtspunkten getrennten Bänden, oder in durchlaufender alphabetischer Reihe zu erscheinen habe, überlasse ich dem verehrl. XII. Internationalen Geologenkongress.

Die Veröffentlichung der einzelnen Artikel in verschiedenen Sprachen dürfte nach dem Dafürhalten des Unterzeichneten keine grossen Schwierigkeiten verursachen, da die alphabetische Verschiebung, welche dadurch verursacht würde, nur gering wäre, und da überdies jeder stratigraphische Name im Folge des entwickelten Programmes grundsätzlich stets in der Sprache behandelt würde, in welcher er zuerst aufgestellt wurde. Daher stimmt der Gefertigte mit Herrn F. A. Bather auch darin überein, dass stratigraphische Unikus in der Sprache zu geben seien, in welcher sie zuerst aufgestellt wurden, selbst wenn diese keine der vier in Aussicht genommenen sein sollte. Auf die Angabe der "eventuellen späteren Verschiebung oder Modifizierung des Begriffes" glaubt der Unterzeichnete nicht verzichten zu sollen, da das Werk durch Weglassung dieser Angaben zu einem Torso würde. Es hat übrigens auch keines der anderen Komiteemitglieder diesen Wunsch ausgesprochen.

Was nun die Einwände des Herrn A. Karpinsky anlangt, so muss zunächst festgestellt werden, dass sich der Unterzeichnete in dem Verlangen, "dass stratigraphische Namen in der Sprache und Alphabet ihrer erstmaligen Aufstellung oder ihrer allgemeinen Landesverwendung im Lexikon Platz finden sollen" vollkommen übereinstimme. Dagegen glaubt der Unterzeichnete dem Verlangen Karpinsky's das ganze Lexikon, oder wenigstens jeden einzelnen Band (N.B. bei geographischer Einteilung des Werkes) in einheitlicher Sprache zu veröffentlichen aus mehreren Gründen entschiedenst entgegentreten zu sollen. Zunächst werden die Schwierigkeiten bei Herausgabe des Werkes dadurch dass ein grosser, unter Umständen auch der grösste Teil der Artikel erst einer Uebersetzung unterzogen werden müssen, bedeutend vermehrt, und in Folge dessen auch der Zeitpunkt des Erscheinens stark hinausgerückt werden, abgesehen davon, dass viele Artikel durch die Uebersetzung auch an Prägnanz verlieren würden. Endlich würde durch das Erscheinen des Werkes in einer fremden Sprache die Verbreitung der "regionalen Hefte" die vorgesehen sind, (siehe unten) erheblich eingeschränkt werden. Dem Wunsche KARPINSKY's, dass die Beiträge der Fachgenossen nicht honoriert werden sollen, kann sich der Gefertigte auch nicht ohne weiteres anschliessen, denn dadurch würden eine ganze Reihe wertvoller Kräfte, die in Folge enger materieller Verhältnisse auf den Bezug eines Honorares angewiesen sind, dem Unternehmen verloren gehen, und tatsächlich fragen auch sowohl BATHER als BRANCA sofort nach der Höhe des zu gewärtigenden Honorars, bevor sie an die Zusammenstellung der Mitarbeiter herantreten. Ein weiterer Grund für die Beibehaltung eines Honorars einzutreten liegt jedoch für den Unterzeichneten auch darin, dass der Herausgeber und Redakteur hierdurch doch bis zu einem gewissen Grade die Mitarbeiter in die Hand bekommt, und dadurch vielleicht einer Verschleppung in der Ablieferung der Manuskripte vorbeugen kann. Die weitere Anregung KARPINSKY's die Regierungen, resp. geologischen Anstalten der einzelnen Länder zur Subventionierung heranzuziehen, erscheint dem Unterzeichneten sehr beachtenswert, und derselbe hat in dieser Beziehung sich auch bereits verschiedentlich zu orientieren gesucht. Sowohl die Auskunft des *United States Geological Survey* als auch eine Nachricht der ungarischen Fachkollegen liess jedoch erkennen, dass solche Subventionen nur unter gewissen Bedingungen zu haben [illegible] dürften, nämlich dann, wenn der das subventionierende Land [illegible] auch in einem separaten Hefte erscheinen würde. [illegible] Unterzeichnete sich erlauben in Ergänzung des an der [illegible] Programmes dem verehrl. XII. Internationalen Geologenk[illegible] Anregungen zu unterbreiten:

"Der verehrl. XII. [illegible] Geologenkongress möge an die einzelnen Staaten [illegible] derselben herantreten und dieselben, resp. deren [illegible] Landesanstalten, zur Subventionierung des Internationalen Stratigraphischen Lexikons auffordern. Dafür wird nach Vollendung jedes einzelnen Bandes (resp. nach Vollendung des ganzen Werkes) eine Ausgabe in *regionalen Heften* veranstaltet werden."

Ob die Herausgabe der einzelnen Bände (den nur bei geographischer Aufteilung der Materie wäre dies überhaupt möglich) durch den jeweiligen Kongress stattzufinden hat, darüber will der Unterzeichnete keine Entscheidung fällen. Den Wünschen KARPINSKY's bezüglich eines russischen Subkomitees, sowie bezüglich der Verlegung des Manuskriptschlusses auf den Januar 1916 tritt der Unterzeichnete bei.

Was endlich der Preis von 1 M. per Druckbogen anlangt, der von zwei Seiten (BATHER und KARPINSKY) als zu hoch beanständet wurde, so hängt die Höhe desselben nur von der zu erreichenden Höhe der Subvention ab.

Zum Schlusse sei noch erwähnt, dass ausser den Mitgliedern des Komitees sich vorläufig noch folgende Herren zur Mitarbeiterschaft bereit erklärt haben: W. DIETRICH (Stratigraphie Würtembergs), E. HENNIG (Mesozoikum, eventuell Neozoikum Norddeutschlands), R. DOUVILLÉ, P. LEMOINE (Bassin de Paris), P. FALLOT (Südfrankreich), TH. TSCHERNYSCHEW, NIK. ANDRUSsow, A. Netschajew, D. Archangelsky, A. Borissiak, A. Pawlow und für Österreich-Ungarn H. Vetters und Fr. Schafarzik.

Endlich muss, weil von verschiedenen Seiten angeregt, hier noch die Frage aufgeworfen werden, ob in dem projektierten Internationalen Stratigraphischen Lexikon *alle* stratigraphischen Namen ihren Platz zu finden haben, wie es von dem Unterzeichneten ursprünglich in Aussicht genommen wurde, oder ob nur die Lokalbezeichnungen aufzunehmen sind, während die allgemeineren Bezeichnungen, wie *Oxford, Laramie, Silur, Aptien,* etc. etc. wegbleiben.

Indem ich das an der Spitze stehende Programm und die daran geschlossenen Anregungen dem verehrlichen XII. Internationalen Geologenkongress zur Erwägung und Beschlussfassung unterbreite,

zeichen ich

in ausgezeichneter Hochachtung

ergebenst

L. Waagen.

Wien, am 13 Mai 1913.

Wien, den 4. Juli 1913.

Herrn Direktor R. W. Brock, M.A., F.R.S.C.,

Generalsekretär des XII. Internationalen Geologenkongresses,

Ottawa.

Sehr geehrter Herr Direktor!

Im Nachtrage zu meinem Berichte an den verehrl. XII. Internationalen Geologenkongress vom 13. Mai d. J. über das "Internationale Stratigraphische Lexikon" muss ich Ihnen leider die Mitteilung machen, dass es mir leider nicht möglich ist an der Tagung dieses Kongresses teilzunehmen. Ich bitte Sie daher, mein Fernbleiben freundlichst bei der Kommission entschuldigen zu wollen, und den Ausdruck meines Bedauerns vermitteln zu wollen.

Ich erlaube mir auf diesem Wege nochmals die Angelegenheit des Lexikons dem verehrl. Kongresse wärmstens zu empfehlen, mit der Bitte besonders die materielle Seite dieses Unternehmens sichern zu wollen. Nach Kenntnisnahme des übersandten Exposées wurde von vielen Seiten nochmals die Wichtigkeit eines Honorars für die Herren Mitarbeiter hervorgehoben, mit dem Hinweise, dass die Mitarbeit—zum Unterschiede von der "Palaeontologia Universalis" oder der "Internationalen Geolog. Karte"—für den einzelnen bloss eine, unter Umständen ausserordentlich mühsame Arbeit aber keine wissenschaftliche Förderung bedeutet, so dass eben durch Gewährung eines Honorares erst ein gewisser Anreiz geboten werden müsste.

Mit dem Ausdrucke ausgezeichneter Hochachtung

ergebenster

Dr. Lukas Waagen.

COMPOSITION DE LA COMMISSION DU LEXIQUE DE STRATIGRAPHIE.

Allemagne, W. Branca.
Autriche, L. Waagen, Président.
Espagne, J. Almera.
États-Unis, C. D. Walcott.
France, W. Kilian.
Grande Bretagne, F. A. Bather.
Italie, C. De Stefani.
Portugal et Suisse, P. Choffatt.
Russie, A. Karpinsky.
Scandinavie, A. Hennig.

COMMISSION DE LA CARTE GÉOLOGIQUE INTERNATIONALE DE L'EUROPE.

(Constituée au IIe Congrès, Bologne, 1881 et au XIe Congrès, Stockholm, 1910, cette commission est chargée de la publication d'une carte géologique du monde à une échelle convenable en outre de celle de l'Europe.)

RAPPORT DE LA COMMISSION DE LA CARTE GÉOLOGIQUE INTERNATIONALE DE L'EUROPE.

Le travail pour compléter la première édition de la carte se poursuit depuis le XIe Congrès international à Stockholm.

A part les quarante feuilles déjà publiées à cette époque les feuilles G 1, G 2, G 3, G 4 et G 5 ont été complétées depuis, tandis que les feuilles E 1, et F 1, la légende en couleurs préparée par Messieurs Tschernyschew Mrazec et Karl Schmidt, et les titres de la carte seront prêts avant le 1er septembre de cette année.

De sorte que la première édition complète sera prête pour la distribution en septembre.

La seconde édition est en marche.

La nouvelle planche gravée de la base topographique, comprenant les feuilles C 4, C 5, D 4, D 5, est presque terminée, ainsi que la révision géologique des feuilles C 1 et B 4.

Comme les gouvernements de plusieurs pays retardent de faire connaître leur décision à l'effet de participer aux frais de la seconde édition, la Commission, d'après les résolutions prises au XIe Congrès international à Stockholm, prie les représentants de s'adresser à leur gouvernements respectifs pour obtenir les fonds requis.

Berlin, le 14 juillet, 1913.

F. Beyschlag.
P. M. Termier.
Th. Tschernyschew.
E. Tietze.

RÉSOLUTIONS CONCERNANT LA CARTE GÉOLOGIQUE INTERNATIONALE DE L'EUROPE ET LA NOUVELLE CARTE MONDIALE.

L'on propose au XIIe Congrès géologique international au Canada, de prendre les résolutions suivantes concernant la réédition de la Carte géologique internationale de l'Europe et celle de la Carte Géologique internationale du monde.

(1) La commission prend connaissance de l'état actuel des travaux des cartes, de l'Europe et mondiale, revues dans le rapport de la direction des cartes.

(2) Les représentants des différents pays sont priés de nouveau de faire les démarches nécessaires auprès des gouvernements concernant leur abonnement.

(3) Les épreuves de la carte mondiale à l'échelle de 1:5,000,000 faites à Berlin sont acceptées, quant à la méthode de projection, à l'échelle et au dessin topographique.

(4) Outre cette décision le Comité s'est occupé de la proposition de M. DE MARGERIE concernant l'édition des cartes géologiques des continents. Quant à cette proposition, le Comité émet le vœu que les cartes géologiques des continents soient dressées à l'échelle uniforme de 1 : 5,000,000, chacune ayant un centre de projection distinct en prenant la carte géologique de l'Amérique du Nord comme modèle. On prend la décision que l'Europe et l'Asie seront considérées comme unité géologique et géographique.

(5) La direction des cartes sera chargée de l'exécution du travail de la carte mondiale. Elle est invitée à se mettre en rapport avec les auteurs les plus compétents des pays intéressés des divers continents.

(6) La Commission demande que les personnes suivantes fassent aussi partie du Comité:—

Afrique australe, E. T. MELLOR.
Afrique occidentale, H. HUBERT.
Algérie, E. FICHEUR.
Allemagne, J. P. KRUSCH.
Brésil, O. A. DERBY.
Chili, E. MAIER.
Congo, J. CORNET.
Côte d'Or, A. E. KITSON.
Egypte, W. F. HUME.
France, E. DE MARGERIE.
Indes anglaises, L. L. FERMOR.
Indo-Chine, J. DEPRAT.
Indes néerlandaises, G. A. F. MOLENGRAAFF.
Italie, V. NOVARESE et C. F. PARONA.
Japon, K. INOUYE.
Madagascar, A. LACROIX.
Maroc, L. E. GENTIL.
Nouvelle-Zélande, P. MARSHALL.
Pérou et Bolivie, G. STEINMANN.
Russie, C. BOGDANOVITCH.

(7) La Commission a le droit d'admettre les représentants des services géologiques qui pourraient être établis jusqu'à l'ouverture du prochain Congrès.

A. STRAHAN.
G. O. SMITH.
E. TIETZE.
TH. TSCHERNYSCHEW.
A. RENIER.
P. KRUSCH.
R. W. BROCK.

Adopté à la séance du Conseil, le 13 août et à la séance générale, le 14 août.

COMPOSITION ACTUELLE DE LA COMMISSION DE LA CARTE GÉOLOGIQUE INTERNATIONALE DE L'EUROPE ET LA NOUVELLE CARTE MONDIALE.

I. Carte Géologique Internationale de l'Europe.

Allemagne, J. Beyschlag, J. P. Krusch (Directeurs-gérants).
France, P. M. Termier.

Grande Bretagne, A. Geikie, A. Strahan.

Italie, G. Capellini, V. Novarese, C. F. Parona.
Autriche-Hongrie, L. v Lóczy, E. Tietze.
Russie, C. Bogdanovitch, A. Karpinsky, J. J. Sederholm (pour Finland).

Membres additionels choisis pour représenter leur pays respectifs.

Belgique, A. Renier.
Danemark, V. Madsen.
Espagne, L. de Adaro.
États Balkanique, L. Mrazec.
Norvège, H. Reusch.
Pays-Bas, (à nommer).
Portugal, Ferreira Roquette.
Suède, J. G. Andersson.
Suisse, Karl Schmidt.

II. Carte Géologique Internationale du Monde.

Australie, T. W. E. David.
Canada, R. W. Brock.
États Sudamericains, H. Keidel.
États Unis, G. O. Smith, B. Willis.
Mexique, J. G. Aguilera.

Membres additionels choisis pour représenter leurs pays respectifs.

Afrique australe, E. T. Mellor.
Afrique accidentale, H. Hubert.
Algerie, E. Ficheur.

Bolivie et *Pérou*, L. Mrazec.
Brézil, O. A. Derby.
Congo, J. Cornet.
Chili, E. Maier.
Côte d'Or, A. E. Kitson.

Egypte, W. F. Hume.
France, E. de Margerie.
Inde anglaise, L. L. Fermor.
Indes néerlandaises, G. A. F. Molengraaff.
Indo-Chine, J. Deprat
Japon, K. Inouye.
Madagascar, A. Lacroix.
Maroc, L. E. Gentil.
Nouvelle Zélande et *Tasmanie*, P. Marshall.

COMMISSION INTERNATIONALE DES GLACIERS.

(Constituée au VIe Congrès Zurich, 1894).

RAPPORT DE LA COMMISSION INTERNATIONALE DES GLACIERS.

par M. Charles Rabot, Président.

Aujourd'hui, comme lors de notre dernière réunion à Stockholm, le régime dominant des glaciers est le recul. Mais cette décroissance ne revêt pas partout la même intensité. Si dans quelques régions, telles que l'Islande méridionale, elle est peu accentuée, dans d'autres, au contraire, comme certains districts de l'Alaska, la Norvège et les Alpes, elle acquiert une remarquable ampleur. Ainsi, dans les massifs français situés immédiatement au sud du Pelvoux, où le phénomène glaciaire ne se manifeste que sous la forme modeste de petits glaciers de cirque, ce recul a abouti à une véritable déglaciation. Au cours de ces trente dernières années plusieurs appareils de cette région ont complètement fondu.

Cette décrue, qui, en Norvège, dure depuis un siècle environ et dans les Alpes depuis 50 à 60 ans, a été, comme on le sait, interrompue de temps à autre, par des crues épisodiques de courte durée et de faible ampleur. Durant les premières années de ce siècle une crue a commencé à se manifester en Norvège, laquelle a progressivement affecté les principaux massifs de ce pays. En cinq ans deux des glaciers issus du Jostedalsbræ ont avancé de 132 m.; un troisième de 104 m. En 1910, la progression s'était ralentie; l'année suivante elle était devenue incertaine; en 1912 elle a pris complètement fin. Il y a donc tout lieu de voir dans le phénomène survenu en Norvège une variation positive secondaire.

Dans les Alpes françaises, depuis 1906 la régression s'est, pour ainsi dire, arrêtée. Durant ces sept dernières années les glaciers du versant français du Mont Blanc ont même manifesté des tendances à entrer en crue. En 1906, 1907 et 1908 le glacier de Bionnassay a éprouvé une très légère poussée en avant, puis, après avoir de nouveau reculé pendant deux ans, a fait une progression de quelques mètres en 1911 et en 1912. A son tour, en 1909, le glacier des Bossons a quelque peu avancé, après quoi il s'est retiré en 1910, l'année suivante, s'allonger de 40 à 50 mètres dans une partie de son front et demeurer stationnaire en 1912. Cette oscillation a ramené la partie la plus avancée du front au point qu'elle occupait en 1904. Depuis 1909 également, le glacier du Tour est en crue; ce mouvement, d'abord très faible, a atteint, de juillet 1910 à juillet 1911, une ampleur de 100 m., puis s'est atténué. A la suite d'une inspection effectuée il y a quelques semaines, M. Paul Mougin, conservateur des Eaux et Forêts, chargé de la direction des observations glaciaires dans le massif du Mont Blanc, nous annonce que tous les glaciers de cette région sont actuellement en crue. En Dauphiné, depuis 1907 est survenu un enneigement progressif très accusé et plusieurs glaciers manifestent des tendances à la progression. Pareillement, les petits glaciers des Pyrénées montrent un notable gonflement.

La recurrence de symptômes de crue au Mont Blanc trente-cinq ans environ après la dernière variation positive secondaire constitue, nous semble-t-il, une vérification intéressante de la loi de Brückner.

Tout récemment, grâce à M. Paul Mougin, un progrès d'une importance considérable a été réalisé dans la connaissance des variations glaciaires aux siècles passés. De judicieuses recherches dans les archives ont livré à notre collègue une série de documents authentiques révélant le régime des glaciers de Chamonix depuis 1580 jusqu'au commencement du XVIIIe siècle. Très prochainement, notre confrère fera connaître toutes ces pièces accompagnées d'une remarquable iconographie dans un nouveau volume de la série glaciologique, publiée par la Direction générale des Eaux et Forêts; en attendant, M. Dabat, Directeur général de cette administration, a bien voulu m'autoriser à indiquer dès maintenant les lignes principales de cette découverte.

Pour permettre de tirer des documents récoltés par M. Mougin toutes les conclusions utiles, il est bon de rappeler la topographie de l'extrémité inférieure du glacier des Bois, autrement dit de la Mer de Glace, le plus fréquemment visité des appareils de Chamonix. En état de grand minimum, comme il l'est aujourd'hui, ce glacier se termine dans une gorge sur une barre rocheuse, à l'altitude de 1,300 m., tandis qu'en crue il passe par dessus ce verrou et vient s'étaler jusqu'à la côte 1,100 m. dans la vallée même, devant le village des Bois.

En 1580, les glaciers de Chamonix, quoique déjà très gros, n'étaient pas encore en état de maximum; ils ne descendaient pas complètement, en effet, dans la vallée; ("descendunt fere usque ad dictam planitiem," dit un texte).

Cet événement se réalisa bientôt. Dans les dernières années du XVIe siècle ou dans les premiers du XVIIe survint une crue considérable, d'un caractère calamiteux pour les riverains. Des terres cultivées furent envahies et des habitations renversées. Des pièces authentiques datant de 1605 et de 1610 mentionnent la destruction par le glacier des Bois des hameaux du Chastellard et de Bonnenuict et l'abandon du village des Bois "à cause des dits glassiers". En même temps le glacier d'Argentière recouvrit sept maisons.

En 1643, nouvelle crue qui également renverse quelques habitations, détruit des champs cultivés et menace le village des Bois.

En 1664, troisième poussée en avant qui dure jusque vers 1685, enfin, en 1716, quatrième crue, mais assez faible, semble-t-il.

Dans l'intervalle de ces quatre progressions, et postérieurement à la dernière, les glaciers ont reculé, mais relativement très peu. En 1730, suivant les recherches de M. Paul Mougin, la mer de glace ne se trouvait éloignée du village des Bois que de 400 mètres et, en 1741 et en 1742, elle s'étendait encore dans la plaine, au bas du verrou rocheux; durant cette période elle était donc très grosse, comparativement à son état actuel.

Les événements qui ont suivi sont connus; ce sont dans le dernier quart du XVIII^e^ siècle, une nouvelle crue qui atteint son apogée en 1818-1820, et qui, coupée de petites régressions, se prolonge sous une forme atténuée jusqu'au milieu du XIX^e^ siècle, puis la grande régression contemporaine. En passant, signalons qu'au début ce recul fut très lent; en 1874, alors que la Mer de Glace était en régression depuis plus de quinze ans, je l'ai vue dans la plaine, où elle se terminait par une magnifique grotte de glace, la grotte de l'Arveyron célèbre à cette époque déjà lointaine.

De cette historique des variations glaciaires dans le massif du Mont Blanc que M. PAUL MOUGIN vient d'établir avec un soin et une compétence qui lui méritent notre reconnaissance, se dégagent deux faits très importants:

Le premier, c'est au début du XVII^e^ siècle la destruction de hameaux et d'habitations par les glaciers. Les montagnards ne construisent pas leurs demeures dans des sites exposés; c'est donc la preuve qu'en 1,600 environ, les glaciers de Chamonix ont acquis des dimensions que depuis plusieurs générations ils n'avaient jamais atteintes et qu'ils avaient été très réduits pendant une très longue période antérieure.

Notre collègue, le Dr. J. REKSTAD a découvert dans les archives de Norvège mention de phénomènes analogues. Durant la première moitié du XVIII^e^ siècle, des branches du Jostedalsbræ et du Svartisen ont renversé des habitations et envahi des terres cultivées. Enfin, en Islande, une extension de la glaciation semble s'être produite depuis le X^e^ siècle.

Une vague d'englaciation a donc touché plusieurs massifs d'Europe à une époque toute récente.

La seconde conclusion, laquelle vient à l'appui de la première, c'est que depuis 1580 les glaciers de Chamonix, ou tout au moins celui des Bois ne paraissent pas avoir éprouvé un minimum aussi accusé que celui régnant aujourd'hui.

Ces observations tendent à prouver que, comme nous avons tenté de le démontrer il y a plusieurs années, il existe des variations glaciaires de deux classes, des variations primaires de durée plus ou moins longue et de grande amplitude, et des variations secondaires survenant à l'intérieur des premières.

Ces oscillations sont la résultante de variations climatériques; aussi bien, me semblerait-il utile d'accompagner nos rapports annuels de notes brèves sur le régime climatérique correspondant à la période embrassée par les observations glaciaires. Tous les ans, dans l'Annuaire du Musée de Bergen (Bergens Muséums Aarbok), notre collègue, le Dr. REKSTAD publie un rapport sur les glaciers de Norvège accompagné de notes indiquant la température moyenne de l'été et sa différence avec la normale, ainsi que la somme des précipitations hivernales et leur écart par rapport à la moyenne. C'est là un exemple qu'il me semblerait très utile de suivre.

Depuis notre dernière réunion, la mort a fait de cruels vides dans nos rangs. FOREL nous a été enlevé l'an dernier. Par l'aménité de ses manières, la sûreté de son caractère, et la droiture de son esprit, notre ancien président avait conquis, je ne dirai pas seulement notre amitié, mais encore notre affection. Nous l'aimions comme un membre de notre propre famille et sa disparition a été pour tous un deuil profondément ressenti. FOREL n'a-t-il pas été le créateur de cette grande famille que forme en quelque sorte la Commission Internationale des Glaciers et l'initiateur de nos études? Le premier, il comprit l'intérêt de l'observation des variations glaciaires et à cette œuvre il s'appliqua pendant 32 ans avec un zèle admirable, suscitant partout des élèves et des continuateurs qui garderont le souvenir de ses enseignements. C'est à son initiative qu'est dû l'éclat acquis aujourd'hui par nos études.

Tout récemment une fin prématurée nous a également privé d'un collaborateur de haute valeur, le professeur RALPH TARR. Quoique jeune, TARR avait conquis une place de premier rang par ses explorations des glaciers de l'Alaska avec le professeur LAWRENCE MARTIN. L'intéressante découverte que son collègue et lui ont faite de l'influence exercée par les tremblements de terre sur le régime des glaciers présente un intérêt de premier ordre. Si la mort nous a privé d'actif collaborateurs, de tous côtés de nouvelles activités naissent et viennent nous apporter de précieux concours. D'année en année, l'étude des glaciers suscite un nombre d'adhérents de plus en plus grand.

Le Comité demande qu'il soit continué.

Adopté à la séance du Conseil du 13 août et à la séance générale du 14 août.

COMPOSITION DE LA COMMISSION INTERNATIONALE DES GLACIERS.

A. Bureau de la Commission.

Président d'honneur: S. A. le prince ROLAND BONAPARTE, Avenue de Iéna 10, Paris.
Président: M. CHARLES RABOT, rue Edouard Détaille 9, Paris.
Secrétaire: M. ERNEST MURET, Inspecteur des Forêts, Lausanne.

B. Membres ordinaires.

Allemagne: Prof. Dr. S. FINSTERWALDER, Hochschule, München.
Argentine: Prof. Dr. FR. PORRO, directeur de l'Observatoire, La Plata.
Autriche: Prof. Dr. ED. BRUCKNER, Universität, Wien.
Danemark: Dr. PAUL HARDER, Kobenhavn.
États-Unis: Dr. H. F. REID, John Hopkins University, Baltimore, Md.
France: S. A. le Prince ROLAND BONAPARTE, 10 Avenue d'Iéna, Paris; M. CHARLES RABOT, 9 rue Edouard Détaille, Paris.
Grande-Bretagne: M. D. W. FRESHFIELD, 1 Airlie Gardens, Campden Hill, London, W.
Italie: Prof. OLINTO MARINELLI, 39 Via San Gallo, Florence.
Norvège: M. P. A. OYEN, Asker près Christiania.
Russie: Le Général J. DE SCHOKALSKY, Torgovaja 27, St.-Pétersbourg.
Suède: Prof. Dr. AXEL HAMBERG, Université, Upsala.

Suisse: Prof. Dr. F. A. Forel, Morges, Lausanne; M. Ernest Muret, Inspecteur des forêts, Lausanne.

Terres polaires antarctiques: Prof. Dr. Erich von Drygalski, Université, München.

Terres polaires arctiques: Prof. Baron de Geer, Université, München.

C. Membres correspondents.

Afrique: Dr. F. Jaeger, Privatdocent à l'Université, Heidelberg, Allemagne.

Allemagne: Prof. Dr. A. Penck, Universität, Berlin; Prof. Dr. A. Blümcke, Maximilianstrasse 8, Augsburg; Prof. Dr. Hans Hess, Kaulbachstrasse 22, Nürnberg.

Autriche: Prof. Dr. Hans Angerer, Klagenfurt.

Danemark: Dr. K. J. V. Steenstrup, Köbenhavn; Prof. Dr. Th. Thoroddsen, Köbenhavn.

États-Unis: M. George Vaux, 404 Girard Building, Philadelphia, Pa; M. G. K. Gilbert, U.S. Geol. Survey, Washington, D.C.

France: Prof. Dr. W. Kilian, Université, Grenoble; M. J. Vallot, rue Cotta 37, Nice; M. Fr. Schrader, rue Madame 75, Paris; M. G. Flusin, Université, Grenoble; M. Paul Mougin, Inspecteur des forêts, Chambéry; M. Charles Jacob, Université, Bordeaux.

Grande-Bretagne: M. A. P. Harper, Greymouth, New Zealand; Major C. G. Bruce, London W.

Italie: Le Général Carlo Porro, Santa Maria della Bicocca, Torino.

Norvège: Dr. H. Reusch, Directeur du Service géologique, Christiania.

Russie: Prof. Dr. B. B. Saposchnikov, Tomsk (Sibérie); M. Nicolas de Poggenpohl, St.-Pétersbourg.

Suède: Prof. Dr. A. G. Nathorst, Académie royale des Sciences, Stockholm; Dr F. W. Svenonius, Service géologique, Stockholm.

Suisse: Dr. J. Coaz, Eidg. Oberforstinspektor, Bern; Prof. Dr. A. Heim, Université, Zürich.

COMMISSION DU DEGRÉ GÉOTHERMIQUE.

(Constituée au Xe Congrès, Mexico, 1906).

LETTRE DE M. BECKER.

Toronto, August 10th, 1913.

The President and Members of the International Geological Congress.
Gentlemen:

I have the honour to transmit herewith a letter from the secretary of the "Commission Spéciale pour étudier les variations du Degré Géothermique", in which are ennmerated the somewhat discouraging difficulties with which he has had to contend.

So far as the United States are concerned I beg to state that, though little has been accomplished, a beginning has been made. The Geological Survey has recognized in principle the duty of investigating underground temperatures, and for a year past designs and patterns of thermometric apparatus have been under consideration and trial. The plans comprise electrical devices by which a complete record of especially important or typical wells can be taken in a few hours and maximum mercurial thermometers with special winding apparatus of a very portable description, by means of which the chief data may be obtained from a great number of borings.

It is hoped that next year a properly qualified geologist may be assigned to devote the entire season to temperature measurements in various portions of the United States, gathering the data for a geological section as well at each bore-hole.

It is also planned to collect specimens for the determination of radio-activity at the same time, so that a comparison may be made between the gradient due to various causes, and arrangements have been made to secure authoritative measurements of the amount of radio-activity in each specimen.

Only a small allotment could be spared during the past year for examination of the gradient, the supervision of which has been placed in my hands.

I beg leave to suggest to the Congress the desirability of combining radio-active surveys with those of the normal geothermic gradient.

If the members of the Committee assent, I suggest that the Committee be continued, with instructions to report at the next meeting of the Congress.

Respectfully submitted,

George F. Becker,
Chairman.

RÉSUMÉ DE LA LETTRE DE M. HALET, SECRÉTAIRE DE LA COMMISSION.

M. HALET dit dans sa lettre qu'en raison de la publication tardive du *Compte Rendu* de la session de Stockholm et pour d'autres raisons, c'est seulement au prix de beaucoup de démarches, de temps et d'argent qu'il a finalement réussi à récueillir une liste complète des représentants des divers pays. Il recommande qu'une circulaire imprimée soit envoyée aux frais du Congrès à chaque membre de la Commission pour expliquer exactement à chacun ce que l'on attend de lui, car il est impossible d'accomplir un travail de quelque valeur si l'on ne demande pas des renseignements très nettement indiqués. Il croit qu'une circulaire de ce genre pourrait être préparée par quelques uns des membres du Congrès à Toronto et envoyée sous les auspices du Congrès.

LISTE DES MEMBRES DE LA COMMISSION SPÉCIALE POUR ÉTUDIER LES VARIATIONS DU DEGRÉ GÉOTHERMIQUE.

A. Membres de la Commission provisoire du Degré géothermique.

(Voir page 172 du *Compte Rendu* du XIe Congrès géologique international.)

Président: G. F. BECKER, États-Unis d'Amerique.
Secrétaire: F. HALET, Belgique.

C. ALIMANISTEANO, Ingénieur en chef, Directeur du département de l'Agriculture, de l'Industrie, du Commerce et des Domaines de la Roumanie, Bucarest.

R. D'ANDRIMONT, Ingénieur géologue, Secrétaire de l'Association des Ingénieurs sortis de l'École de Liége, Liége.

H. VON HÖFER, Professeur à l'École des Mines de Leoben.

L. A. JACZEWSKI, Géologue au Comité géologique de Russie, St.-Pétersbourg.

E. LAGRANGE, Professeur à l'École Militaire, Bruxelles.

L. DE LAUNAY, Professeur à l'Ecole supérieure nationale des Mines, Paris.

J. LIBERT, Inspecteur général des Mines, Liège.

M. LOHEST, Professeur, Liège.

S. STRASSART, Professeur d'exploitation des mines à l'École provinciale du Hainaut, Mons.

TH. TSCHERNYSCHEW, Directeur du Comité géologique de Russie, St.-Pétersbourg. (Décédé en 1911).

B. Membres élus par les directeurs des services géologiques des divers pays.

(Voir page 145 du *Compte Rendu* du Xe Congrès géologique international.
Les Services géologiques de plusieurs pays (Espagne, France, Italie, Japon, etc.) n'ont pas encore nommé leurs représentants).

Argentine: R. Stappenbeck, Chef de la Section hydrogéologique du Ministère de l'Agriculture, Buenos Aires.

Australie occidentale: A. G. Maitland, Government Geologist, Perth.

Baden: J. Königsberger, Professeur à l'Université de Freiburg

Belgique: F. Halet, Ingenieur, Chef de Section au Service Géologique de Belgique, Bruxelles.

Canada: R. W. Brock, Directeur du Service Géologique du Canada; O. E. LeRoy, Géologue à la Commission Géologique de Canada.

États-Unis d'Amérique: G. F. Becker, Géologue au Service Géologique des États-Unis d'Amerique.

Grande-Bretagne: A. Strahan, Directeur au Service Géologique d'Angleterre et du Pays de Galles, London; C. H. Lees, Professeur de physique à East London College, London.

Hongrie: L. Loczy de Locz, Professeur, Directeur du Service Géologique de Hongrie, Budapest; T. Szontagh de Igló, Conseiller royal, Sous-Directeur du Service Géologique de Hongrie, Budapest.

Irlande: W. B. Wright, Géologue au Service Géologique d'Irlande, Dublin.

Mexique: E. Ordoñez, Ingénieur des Mines, Mexico.

Norvège: O. E. Schiötz, Professeur de physique à l'Université de Christiania.

Nouvelle Zélande: J. M. Bell, Ancien Directeur du Service Géologique, Wellington.

Prusse: A. Jentzsch, Geh. Bergrat, Professeur, Berlin.

Suède: H. E. Johansson, Ingénieur des Mines, Géologue au Service Géologique de Suède, Stockholm.

Suisse: H. Schardt, Professeur, Veytaux.

Tasmanie: L. K. Ward, Assistant Government Geologist, Launceston

COMMISSION POUR L'ÉTUDE DE L'HOMME FOSSILE.

(Constituée au XIe Congrès, Stockholm, 1910).

Commission chargée d'examiner la proposition relative à la constitution d'une commission internationale pour l'étude de l'homme fossile.

Membres: MM. Boule, W. C. Brögger, K. Gorjanovic-Kramberger, A. Rutot, W. J. Sollas, F. Wahnschaffe.

Cette Commission n'a soumis aucun rapport au XIIe Congrès.

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RAPPORT DU COMITÉ EXECUTIF DU XIIe CONGRÈS GÉOLOGIQUE INTERNATIONAL SUR LA PROPOSITION DU DR. HOBBS RELATIVE A UNE COOPÉRATION INTERNATIONALE POUR L'ÉTUDE DES FRACTURES DE LA CROUTE TERRESTRE.

"The Executive Committee regret that owing to the demands made upon their time in connexion with the preparation of the extended series of excursions arranged for the XIIth International Geological Congress, and the publication of the monograph on the Coal Resources of the World, they have been unable to undertake the preparation of an additional monograph dealing with the fractures of the earth's crust as suggested by the XIth Session of the International Geological Congress. The Committee would, therefore, respectfully request that this task be transmitted to the Executive Committee of the XIIIth International Congress."

Ce rapport a été reçu par le Conseil à sa séance du 11 août.

PROPOSITIONS PRÉSENTÉES AU CONGRÈS.

I. PROPOSITION DE M. J. SAMOJLOFF RELATIVE A UNE ENQUETE SUR LES RESSOURCES MONDIALES D'ACIDE PHOSPHORIQUE.

Au Comité du XIIe Congrès géologique international:

J'ai l'honneur de m'adresser au Comité du XIIe Congrès la proposition d'inscrire au programme du XIIIe Congrès prochain la question des ressources mondiales d'acide phosphorique.

En présence de l'intensité de l'agriculture moderne et de son progrès incessant, la question de la fourniture des engrais minéraux au sol doit être considérée comme l'une des plus essentielles et des plus urgentes.

Parmi les engrais minéraux, les engrais phosphatés, dont la matière première est fournie par les phosphates naturels, jouent un rôle exceptionel par leur importance.

On peut admettre que la quantité d'acide phosphorique contenue dans les phosphates détermine, dans une certaine mesure, la quantité possible de substance vivante du monde.

A côté des gisements de phosphates en Russie, dont les recherches sont exécutées sous ma direction depuis six ans, les dépôts mondiaux de ce fossile ont souvent attiré mon attention.

L'évaluation précise et rigoureuse de ces dépôts ne peut être effectuée, cela va sans dire, qu'en se basant sur les travaux d'exploration collectifs d'une organisation internationale comme cela a été fait au Congrès de la Suède pour les quantités mondiales de minerai de fer et comme cela se passe pour la houille au XIIe Congrès au Canada.

C'est en me basant sur ces faits que je me permets d'adresser au Comité la proposition d'inscrire à l'ordre du jour du XIIe Congrès la question:

Sur l'organisation de travaux collectifs concernant l'évaluation des dépôts mondiaux d'acide phosphorique.

(Signé) J. SAMOJLOFF,

Professeur de Minéralogie à l'Institut agronomique supérieur, Moscou.

La proposition de M. SAMOJLOFF a été prise en considération aux séances du Conseil des 8, 11 et 13 août, et le choix d'un sujet a été laissé aux géologues belges.

LETTRE DE M. ARMAND RENIER RELATIVE A LA PROPOSITION DE M. SAMOJLOFF.

Bruxelles, le 27 juin, 1913.

A M. F. D. ADAMS, Président de la XIIe Session du congrès géologique international, Toronto, 1913, Victoria Memorial Museum, Ottawa.

Monsieur le Président:—

En possession de la quatrième circulaire du XIIe Congrès géologique international, j'y lis, page 9:

"Le Comité exécutif a reçu de M. le professeur SAMOJLOFF de Moscou, Russie, la proposition de faire de la question des ressources phosphateuses mondiales, le sujet principal de discussion du XIIIe Congrès géologique international."

En ma qualité de délégué officiel du Gouvernement, chargé de confirmer au Congrès géologique l'invitation des géologues belges de tenir, en 1916, à Bruxelles, sa treizième session, je crois devoir vous informer, sans plus tarder, que notre Comité d'initiative a déjà recherché le sujet d'enquête mondiale à proposer, et a arrêté son choix sur les réserves en minerais de cuivre.

J'espère que, d'ailleurs, le Congrès voudra bien admettre en principe que le Comité organisateur d'une session a rang de priorité pour faire des propositions fermes relativement à la session qu'il organise, toute proposition faite au Congrès par des géologues ou d'autres associations de géologues ne peuvent revêtir en principe que la forme de vœu.

Veuillez agréer Monsieur le Président, l'assurance de ma considération très distinguée.

(Signé) A. RENIER.

Ingénieur des Mines, Chef du Service Géologique, Délégué au Congrès géologique international de Toronto.

AVIS DE M. W. VERNADSKY REÇU A LA SÉANCE DU CONSEIL DU 11 AOÛT.

M. W. VERNADSKY pense qu'on doit prendre en considération non seulement l'importance pratique de l'évaluation des quantités mondiales du cuivre, du pétrole ou des phosphates, mais aussi l'importance scientifique des chiffres obtenus. L'importance pratique de toutes ces questions est très grande, mais en donnant la quantité mondiale des phosphates nous établissons un fait scientifique nouveau. En déterminant la quantité de la substance organique (matière vivante) dans les différentes périodes géologiques, nous obtenons des données qui sont nécessaires pour la résolution de certains problèmes géologiques et minéralogiques importants.

II. PROPOSITION DE M. F. A. BATHER RELATIVE AU CHANGEMENT DANS LA DATE DE LA SESSION DU CONGRÈS GÉOLOGIQUE INTERNATIONAL.

LONDON, February 11th, 1913.

To the Secretary,
International Geological Congress;

Dear Sir,— In enclosing my subscription as a member of the International Geological Congress I desire to draw the attention of the Council to the fact that, owing to the postponement of the last Congress to an interval of four years instead of three, this Congress, to be held triennially, now falls in the same year as the International Zoological Congress. In 1910 these two Congresses were actually held at the same time of year.

The Committee of Palæontologia Universalis, recognizing the great inconvenience which such an arrangement causes to palæontologists, forwarded to the Council of the Congress, when it met at Stockholm, a request that this interference should be avoided in future. In the Compte Rendu of the XIth International Geological Congress I am, however, unable to find any statement showing that this protest was so much as considered by the Council.

In the present year, it is true, that, owing to the climatic conditions of the Riviera on the one hand and of Canada on the other, the two Congresses are not being held at precisely the same time of year. This, however, makes very little difference to the result so far as palæontologists are concerned. The Zoological Congress being held in F[illegible]e in one of the most expensive pleasure resorts of that continent and at [illegible] height of the season, that is to say, the most expensive time of year, and the Geological Congress, on the other hand, being held on the other side of the Atlantic and involving, if one is to obtain any benefit from it, considerable expenditure in addition to the mere cost of the trans-Atlantic passage, it will be clear that any one who attends both Congresses will be called upon for a very heavy pecuniary expenditure, in addition to the considerable expenditure of time. Palæontologists, I need hardly point out, are not among the richer members of the community, even of the geological community, and there cannot be many among them able to afford two international congresses in the same year.

For my part, it was a source of great regret to me that I was unable to attend the Zoological Congress at Graz three years ago. This year, owing to the important questions that are coming up for discussion, I feel that it is my duty to attend the Zoological Congress at Monaco, and indeed I am delegated by the Zoological Society of London to represent its views on these disputed questions. Unfortunately, I also have the honour to be a member of two important Committees of the International Geological Congress and I deeply regret that I cannot afford to come to Canada in order to take part in their deliberations. I mention these personal matters as a mere illustration of the difficult position in which many earnest workers besides myself have been placed by the action of the Council of the Geological Congress.

At the last Congress, when a member raised in the general assembly of the Council the question of the interval between the Congresses, he was told that, since the invitation had already been made for 1913 by both Belgium and Canada, it was not within the power of the Congress to make any alteration. This year we all know that we are to receive an invitation from Belgium for 1916. Again, therefore, we shall be told that it is not within the power of the Congress to make any alteration and so we shall go on for ever and ever. This, I humbly submit to the Council, is merely ridiculous. I am aware that palaeontologists form a very small portion of the membership of the Congress, but it will scarcely be maintained that they constitute an unimportant section. It is, therefore, to be hoped that on this occasion their views as already expressed by the Committee of Palaeontologia Universalis, will meet with some attention.

I have the honour to be, dear sir,

Yours faithfully,

F. A. BATHER.

Assistant-Keeper of Geology at the British Museum and Delegate of the Trustees of the British Museum.

LONDON, June 28th, 1913.

To the Secretary,

International Geological Congress:

Dear Sir.—I am just in receipt of your letter of June 17th, and thank you for giving me the opportunity of revising or adding to my letter of February 11th. The letter was written with a view to its being laid before the Council and though it is a little long and perhaps somewhat personal, I do not think that it would be advisable to alter it. My experience is that when one tries to be very brief, it only results in lengthening the subsequent discussion.

The matter was not discussed at the Zoological Congress, which, I may point out, has adhered to its original intervals of meeting, whereas the Geological Congress has not done so. Obviously, therefore, the Geological Congress is the first body to approach. The Zoological Congress is to meet at Buda Pest in 1916.

I have only to add that, as the time approaches, my regret at being unable to attend the Congress and the Committees of which I am a member, becomes still more keen.

Yours very truly,

F. A. BATHER.

Par décision du Conseil du 9 août, confirmée par un vote à la séance générale du 11 août, la date de la prochaine session du Congrès est changée de 1916 à 1917.

III. PROPOSITION DE M. J. J. SEDERHOLM INSISTANT SUR L'IMPORTANCE D'UNE COOPÉRATION INTERNATIONALE POUR ÉTABLIR LA CORRÉLATION DES ROCHES PRÉCAMBRIENNES.

TORONTO, August 11th, 1913.

"The International Geological Congress expresses the hope that the governments of those countries which possess contiguous areas of Pre-Cambrian rocks will promote the comparative study of such areas by forming international committees that will include representatives of the Geological Surveys of all the countries concerned, for the purpose of correlating the Pre-Cambrian formations in the different countries."

Adopté à la séance du Conseil du 14 août et à la séance du Congrès de la même date, les mots "geological surveys" ayant été substitués au mot "governments" de la proposition originale.

IV. PROPOSITION DE M. R. W. BROCK, RELATIVE A LA MONOGRAPHIE QUI DOIT ETRE PREPARÉE POUR LE CONGRÈS.

TORONTO, August 13th, 1913.

I beg to propose, in connexion with the next Congress, an International Commission consisting of the General Secretary of the XIIIth Congress and two past general secretaries named by him, to decide upon the size of the monograph to be prepared for the Congress, the number of pages at the disposal of the respective countries and the last date at which manuscripts will be received for publication in the monograph; the Commission to be empowered to rule also as to contributors furnishing their illustrations and maps in a form suitable for reproduction.

(Sgd.) R. W. BROCK.

Cette proposition est adoptée par le Conseil a sa sixième séance et par le Congrès en séance générale le 14 août.

V. PROPOSITION DE M. R. W. BROCK RELATIVE A LA RÉDACTION D'UNE CONSTITUTION POUR LE CONGRÈS INTERNATIONAL GÉOLOGIQUE.

TORONTO, August 13th, 1913.

I beg to propose that a small International Committee be appointed consisting of not more than eight persons, who have had actual experience on the Executive Committees of various sessions of the Congress, to consider the question of a permanent constitution and by-laws and to submit, if possible, a proposal thereon at the next session of the Congress.

(Sgd.) R. W. BROCK.

Cette proposition est approuvée par le Conseil à sa sixième séance et par le Congrès dans la séance du 14 août.

Le Président M. ADAMS, est chargé de constituer le comité et désigne les personnes suivantes:

Président:— M. R. W. BROCK.
Membres:— MM. J. G. ANDERSSON.
C. BARROIS.
A. KARPINSKY.
A. RENIER.
G. O. SMITH.
G. STEINMANN.
E. TIETZE.

VI. PROPOSITIONS RELATIVES AUX LIEUX DE RÉUNION DES PROCHAINS CONGRÈS.

INVITATION DE LA BELGIQUE.

TORONTO 9 Août, 1913.

Conformément aux instructions de M. le ministre de l'Industrie et du Travail et en confirmation de la correspondance échangée entre M. le Président ADAMS et M. le Directeur général des Mines, Président de la Commission géologique de Belgique L. DEJARDIN, j'ai le grand honneur de vous apporter l'invitation formelle et officielle de tenir en Belgique la XIII^e Session du Congrès géologique international. Cette invitation, déjà formulée à deux reprises, n'avait pu être prise en considération mais les géologues belges, assurés qu'ils sont de l'appui du Gouvernement, espèrent fermement que le Conseil voudra bien cette fois transmettre leur invitation à l'assemblée générale du Congrès en l'appuyant d'un avis favorable.

(Signé) A. RENIER,
Chef du Service géologique de Belgique; délégué du Gouvernement de Belgique.

L'invitation de la Belgique est acceptée par le Conseil à sa séance du 9 août, et la décision du Conseil est approuvée par le Congrès dans la séance du 14 août.

INVITATION DE LA RÉPUBLIQUE ARGENTINE.

BUENOS AIRES, le 16 Juin 1913.

A Monsieur le Président du XIIe Congrès géologique international Professeur FRANK ADAMS, Montreal, Canada.

M. le Président:

Les recherches géologiques que fait la Direction générale des Mines, de la Géologie et de l'Hydrologie à ma charge, deviennent de jour en jour plus importantes, ainsi que le démontrent, du reste, les résultats obtenus et l'intérêt qu'elles provoquent dans les milieux scientifiques. Nous tâchons de les connaître autant que possible soit par correspondance épistolaire, soit par la publication de rapports et concernant ce chapitre, nous croyons avoir contribué à l'explication de plusieurs problèmes ayant trait à la géologie du territoire de la République Argentine, laquelle, comme vous le savez, M. le Président, offre une variété de tous points digne d'être soigneusement étudiée.

Si nos services ne sont pas encore assez importants pour embrasser dans ces recherches la plupart des régions du territoire offrant un intérêt plus marqué, la collaboration étrangère devient précieuse alors, et c'est pourquoi nous ne cessons de l'encourager, convaincus du bon résultat qu'elle pourrait obtenir.

C'est un peu pourquoi, aussi, après avoir pris part aux Congrès internationaux de géologie, de la façon la plus complète permise, nous pensons qu'il serait possible pour la République Argentine d'être à son tour choisie, étant donné ses conditions géologiques, pour la réunion d'un de ces congrès.

Cette demande que je me permets de vous faire avec une certaine appréhension, il est vrai, sera ratifiée par le délégué argentin au Congrès, le Dr. JUAN KEIDEL, Chef de la Section Géologique de cette Direction Générale et j'espère qu'elle sera prise en considération par l'honorable assemblée.

Son anticipation répond en outre, aux préparatifs qu'il y aurait lieu de faire, étant donné qu'il s'agit d'un pays de l'hémisphère austral et que, par conséquent, il faudrait profiter de l'époque propice aux excursions à la Cordillère. Grâce au continuel progrès des moyens de transport, ces excursions se feraient dans d'assez bonnes conditions, détail sur lequel j'ose insister auprès de vous, M. le Président, afin que vous en fassiez part à l'assemblée.

Comme principaux buts de ces excursions à la Cordillère, je vous indiquerais les suivants:

Les sédiments mésozoïques du géosynclinal andin, surtout dans les environs de l'Aconcagua; en outre, son intéressante tectonique et la morphologie des grandes hauteurs dans la région du climat sec continuel.

La Précordillère et les parties des chaînes pampéennes dans les provinces de San Juan et de Mendoza, intéressantes par leurs sédiments marins du paléozoïque inférieur (silurien et dévonien), les couches fossilifères du Gondwana, leur tectonique d'âge paléozoïque, la morphologie des terrains bas et déserts et les chaînes pampéennes avoisinantes pour leurs schistes cristallins et leur morphologie.

La chaîne de Cordoba et les chaînes pampéennes de la Rioja, intéressantes par les conditions très favorables qu'elles offrent à l'étude des roches cristallines du précambrien et du paléozoïque, des couches du Gondwana, et par leurs remarquables rapports géomorphologiques et leurs gisements (marbres à Cordoba, minerais d'exploitation à Famatina).

La zone subandine du nord, les grandes vallées longitudinales et le versant oriental de la Puna de Atacama, intéressantes non seulement par l'occasion qu'elles offrent pour l'étude du précambrien et du paléozoïque marin, mais aussi et spécialement, par leur tectonique et les énormes accumulations des *bolsons*.

A part tout cela, on pourrait visiter la région du Rio Negro et la partie est du territoire du Neuquén afin de voir les dépôts fossilifères marins du jurassique supérieur, du crétacé inférieur, les sédiments continentaux du crétacé supérieur, les terrasses et les plateaux septentrionaux de la Patagonie. Cette excursion permettrait aussi de visiter les chaînes pampéennes de la province de Buenos Aires, lesquelles par la découverte de grands dépôts glaciaires du paléozoïque supérieur et leur tectonique sont vraiment intéressantes.

Il serait aussi possible d'organiser une excursion aux régions du nord et du centre de la Patagonie, jusqu'aux grands lacs de la Cordillère, qui offrent de si magnifiques panoramas; mais, pour cela, il faudrait se résigner à souffrir les incommodités des voyages dans des régions où les moyens de transport sont défectueux.

Le Dr. KEIDEL, notre délégué, pourra du reste vous donner toute sorte de détails au sujet de l'intérêt que la République Argentine offre au point de vue géologique.

En exprimant de nouveau l'espoir que cette proposition sera favorablement accueillie, je vous prie, M. le Président, de bien vouloir agréer l'assurance de ma considération la plus distinguée.

E. HERMITTE,
Directeur général.

L'invitation de la République Argentine est lue devant le Conseil à sa séance du 9 août et renvoyée pour être prise en considération à la prochaine session du Congrès en 1917.

INVITATION DE L'ESPAGNE.

Monsieur le Président du XIIe Congrès géologique international:

Les délégués représentant l'Espagne au XIIe Congrès géologique international ont l'honneur de rappeler au Congrès que, lors de la session de Stockholm, leur pays a invité les congressistes à tenir à Madrid la réunion qui suivra celle de Bruxelles.

Les délégués espagnols renouvellent l'invitation de l'Espagne et prient le Conseil de la prendre en considération au cours de ses délibérations.

Recevez, monsieur le Président, nos salutations les plus distinguées.

(Signé) AUGUSTIN MARIN,
E. DUPUY DE LÔME.

TORONTO, le 11 août 1913.

L'invitation de l'Espagne est lue à la séance du Conseil du 9 août et renvoyée pour être prise en considération au XIIIe Congrès.

PUBLICATIONS DISTRIBUÉES AUX MEMBRES DU CONGRÈS.

Le Comité Exécutif, de même que plusieurs services du gouvernement et quelques villes, ont offert aux membres des publications ayant trait à la géologie du Canada ou autres sujets intéressants. Ces publications ont été distribuées principalement par l'entremise d'un bureau d'information au siège principal, dirigé par M. JOHN MCLEISH. Les plus importantes étaient:

Par le Comité Exécutif:

The Natural History of the Toronto Region, publié par le Canadian Institute, Toronto (nombre d'exemplaires limité).

Carte de poche du centre de Toronto et des dépendances de l'Université.

The moraine systems of southwestern Ontario, par FRANK B. TAYLOR.

Numéro spécial du Canadian Mining Journal, publié à l'occasion du Congrès.

Par le Ministère des Mines du Canada:

Division des Mines: Les publications de cette division.

Commission Géologique: Les publications de la Commission; une séries de vues du Musée commémoratif Victoria.

Par le Ministère des Mines de la Colombie Britannique:

Les publications de ce ministère.

Par le Ministère de l'Intérieur du Canada:

The Selkirk range, par O. A. WHEELER (nombre d'exemplaires limité)

Par le Bureau des Mines d'Ontario:

Les publications du bureau.

Par le Bureau des Mines de Québec:

Les publications de ce bureau.

Par le Ministère des Mines de la Nouvelle-Ecosse:

Les publications de ce ministère.

Par le Service Géologique des États-Unis:

Geological Atlas, Niagara Folio (nombre d'exemplaires limité).

Par la Commission du chemin de fer Timiskaming and Northern Ontario.

The mining industry in that part of Northern Ontario served by the T. & N. O. Ry., par ARTHUR A. COLE.

Par la ville de Toronto;
Guide illustré de Toronto.

Par le Smithsonian Institute, aux membres de l'excursion C 1;
Formation cambrienne du district Robson Peak, Colombie Britannique et Alberta, par CHARLES D. WALCOTT.

Par le Gouvernement de la Colombie Britannique, aux membres visitant la Colombie Britannique;
Brochures et cartes ayant trait à cette province.

Par le comité local de Montréal;
Guide officiel de Montréal, petite brochure illustrée historique et descriptive, par C. R. GIRAUD.

Par le comité de Québec;

Historic Quebec, un album reproduisant des vues de Québec, et des environs.

Par la ville d'Ottawa, aux membres visitant Ottawa;
Guide d'Ottawa.

Par la ville de Calgary, aux membres visitant Calgary;
Guide illustré de Calgary.

Par la ville de Victoria, aux membres visitant Victoria;
Guide illustré de Victoria.

Par le bureau de publicité de Winnipeg, aux membres visitant Winnipeg;
Manitoba's Minerals, par le Dr. R. C. WALLACE.

Par le Musée paléontologique royal d'Ontario;
Guide du musée.

Par M. PH. NÉGRIS;
La régression quaternaire, par PH. NÉGRIS.

FÊTES PENDANT LE CONGRÈS.

LA RÉCEPTION À MONTRÉAL.

Au mois d'août les excursionnistes du Congrès sur leur retour ont été l'objet d'une réception à Montréal. Dans l'avant-midi une assemblée spéciale de l'université McGill fut convoquée en l'honneur des congressistes et le diplôme de docteur en philosophie à titre honoraire a été conféré aux six géologues distingués, le professeur H. Backstrom de Stockholm, le professeur H. Bergeat de Koenigsberg, le professeur Kemp de New York, M. Alfred Harker de l'université de Cambridge, et le professeur A. Lacroix de Paris. Des discours de circonstance furent prononcés par les personnes qui présentaient les candidats et, en réponse, par les candidats eux-mêmes chacun dans sa langue propre.

A la suite de cette intéressante cérémonie ces messieurs furent invités à un lunch de la part du comité local de Montréal.

LA RÉCEPTION À OTTAWA.

Il était convenu que les personnes ayant pris part aux excursions A avant la Session se réuniraient à Ottawa le . . . .

A leur arrivée à Ottawa, les membres sont reçus par les représentants du comité local et accompagnés jusqu'à la Ferme expérimentale centrale où un lunch était préparé par ordre du gouvernement. Parmi les fonctionnaires présents à ce luncheon pour souhaiter la bienvenue aux congressistes était le très honorable R. L. Borden, premier ministre du Canada. Le premier ministre souhaite la plus cordiale bienvenue en Canada aux congressistes et exprime sa haute appréciation des objets et visées du Congrès. M. le commissaire Parent souhaite la bienvenue au nom de la ville d'Ottawa. Après les remerciements par M. Adams, président du Congrès, de courtes allocutions sont prononcées par MM. Strahan d'Angleterre, Termier de France, Sederholm de Finlande et Kemp de New-York.

Après le lunch on visite les collections géologiques et minéralogiques de la Commission géologique au Musée commémoratif Victoria et, dans le cours de l'après-midi, les excursionnistes prennent part au dévoilement de la plaque commémorative en souvenir de Sir William Logan dont il est question autre part dans ce volume.

Le thé est ensuite servi au Musée.

RÉCEPTION À TORONTO.

Son honneur le maire et les conseillers municipaux de la ville de Toronto donnent une réception à l'hotel de ville dans la soirée du lundi 11 août, et ces messieurs font la connaissance d'un bon nombre des principaux citoyens de Toronto.

ASSEMBLÉE SPÉCIALE DE L'UNIVERSITÉ DE TORONTO.

Dans l'après-midi du jeudi 14 août, une assemblée spéciale de l'université de Toronto est convoquée dans la salle des facultés. Le chancelier Sir WILLIAM MEREDITH occupe le fauteuil et remet le diplôme de docteur en droit à titre honoraire, aux membres distingués du Congrès dont les noms suivent:—

Oberbergrat Professor RICHARD BECK, de Freiberg, Saxe, présenté par le professeur T. L. WALKER de l'université de Toronto.

Le Professeur T. C. CHAMBERLIN, de l'université de Chicago, Chicago, Ill., présenté par le Professeur A. P. COLEMAN de l'université de Toronto.

M. W. G. MILLER, géologue provincial de Toronto, Ont., présenté par le professeur A. T. DELURY de l'université de Toronto.

M. J. J. SEDERHOLM, de Helsingfors, Finlande, présenté par le professeur B. E. FERNOW de l'université de Toronto.

M. AUBREY STRAHAN, du Service géologique de la Grande Bretagne, Londres, Angleterre, présenté par le président FALCONER de l'université de Toronto.

M. P. M. TERMIER, directeur du Service de la Carte géologique de la France, présenté par le professeur SAINT-ELME DE CHAMP, de l'université de Toronto.

Le professeur THEODOSIUS TSCHERNYSCHEW, de St. Petersbourg, Russie, présenté par le professeur W. A. PARKS, de l'université de Toronto.

Après la cérémonie, les membres du Congrès et les invités assistent à un garden party donné par les gouverneurs de l'université de Toronto dans le carré de l'université.

GARDEN PARTY DONNÉ PAR MONSIEUR ET MADAME DUNLAP.

A l'occasion du Congrès, Monsieur et Madame DAVID A. DUNLAP donnent un garden party en leur demeure, 13 Highland Avenue, Rosedale, dans l'après-midi du samedi 9 août.

Les invités sont reçus par M. et Mad. DUNLAP et se dispersent ensuite dans les magnifiques jardins et bocages, pour se promener au son de la musique des Highlanders et jouir d'une heure ou deux de conversation en aimable compagnie. Pour la commodité des personnes assistant aux séances scientifiques de l'après-midi un service d'automobiles avait été organisé entre l'université et les jardins de Rosedale.

LUNCHEON DONNÉ PAR LES DAMES DE TORONTO.

Le comité des dames de Toronto reçoit les dames du Congrès à un luncheon dans les salons de l'Orateur, aux édifices du parlement provincial, le vendredi 6 août. Des discours sont prononcés par Mesd. FRANK D. ADAMS, J. B. TYRRELL et AUBREY STRAHAN. Après le lunch, on fait un groupe photographique des invités sur le grand escalier de l'édifice.

Toutes les après-midi pendant le Congrès, ce comité a aussi servi le thé aux congressistes dans le carré de l'Université.

LE BANQUET.

Dans la soirée du mercredi 15 août un banquet fut offert aux membres et délégués par le Président et le Comité exécutif au nom du Canada. Le dîner fut servie à l'Arsenal, University Avenue, où l'on avait transformé une partie de l'édifice en salle à dîner champêtre au moyen d'une vaste marquise dissimulée par des plantes vivaces et de la verdure. Le président, M. ADAMS occupait le fauteuil et les autres sièges à la table principale étaient occupés par les délégués des différents pays et les représentants du gouvernement, tandis que les autres membres du Congrès accompagnés dans bien des cas de leurs épouses ou leurs filles, etaient placés à des tables plus petites disposées en avant.

Après que l'on eut bu à la santé du Roi, le président propose un toast en l'honneur du Gouverneur général. L'Hon. M. CODERRE, ministre des Mines du Canada, répond au nom de Son Altesse royale, parti en Angleterre, et après avoir parlé de la grande popularité dont jouissent le duc et la duchesse dans tout le Canada, dit combien Son Altesse royale eut été heureux de se trouver au milieu de tant de visiteurs distingués; puis il espère que le résultat du Congrès sera d'un grand avantage non seulement pour le Canada mais pour le monde entier.

L'Hon. M. HEARST, ministre des Terres, Forêts et Mines, pour la province d'Ontario, répond au toast en l'honneur des Lieutenants-gouverneurs d'Ontario et de Québec, en l'absence du Lieutenant-gouverneur d'Ontario, sir JOHN GIBSON; il explique en quelques mots le système d'administration du Canada par une gouvernement fédéral et des gouvernements provinciaux; il fait res sortir l'immense étendue et les vastes ressources de l'Ontario et fait part au Congrès des meilleurs souhaits de la population de cette province.

L'Hon. M. DEVLIN, miustre de la Colonisation, des Mines et des Pêcheries de Québec, en réponse au même toast, fait quelques remarques préliminaries en anglais et continue son discours en français; c'est un grand honneur pour le Canada, dit-il, qu'on ait choisi ce pays pour la réunion de la XII^e Session du Congrès géologique. Il fait valoir les éminentes qualités de sir FRANÇOIS LANGELIER, lieutenant-gouverneur de Québec, un ami des arts et des sciences, qui s'est vivement intéressé au Congrès et qui eut été enchanté de se trouver en contact avec autant d'hommes éminents venus de l'étranger.

Le Président exprime ensuite au nom des géologues et du peuple canadiens tout le plaisir qu'ils éprouvent d'avoir au milieu d'eux autant d'éminents visiteurs. Après une allusion au magnifique champ d'étude à la portée des géologues du Canada, aux vastes ressources minérales du pays, à sa croissance rapide et à son développement, il souhaite aux étrangers la plus cordiale bienvenue. Parlant ensuite en français il dit combien il est heureux de voir un aussi grand nombre de représentants de la France et des pays de langue française. Puis, évoquant d'anciens souvenirs, il s'adresse aux membres allemands du Congrès dans leur langue propre, pour rappeler les jours heureux qu'il a passé autrefois à Heidelberg, et souhaite particulièrement une cordiale bienvenue aux membres allemands du Congrès.

En annonçant le toast aux membres et délégués de l'étranger, le Président fait en même temps allusion au travail remarquable accompli par le professeur W. G. MILLER et donne lecture d'une lettre d'un groupe d'Ontariens qui s'intéressent aux mines, exprimant leur intention de présenter à M. MILLER son portrait à l'huile en témoignage de leur haute estime. Il fait aussi mention de l'honneur qui lui sera conféré par l'université de Toronto dont il doit recevoir, à titre honoraire, le diplôme de docteur en droit.

Le Président prie M. LINDSEY de proposer le toast et par la même occasion, rappelle toute l'activité déployée par celui-ci dans les travaux de préparation qui ont si bien contribué au succès du Congrès.

M. LINDSEY se lève et, après quelques saillies humoristiques, passe en revue les progrès remarquables de la géologie au siècle dernier et rend hommage au génie des géologues disparus et de ceux encore vivants. Il dit qu'en vue du peu de temps disponible, on n'entendra que quelques réponses à ce toast, et fait l'éloge des travaux accomplis par ceux qui vont répondre.

La parole est à M. STEINMAN qui parle en allemand. Il félicite les organisateurs du Congrès du succès obtenu. Il dit que l'Allemagne apprécie pleinement les travaux remarquables faits par le Canada en vue de préparer ce Congrès qui ne le cède en rien aux congrès précédents. Il remercie les Canadiens de leur aimable hospitalité et leur adresse le vieux cri: Gluck auf! Gluck auf! Gluck auf!

M. TIETZE de l'Autriche-Hongrie parlant aussi en allemand, remercie les géologues canadiens de leur hospitalité et les félicite sur l'heureuse issue du Congrès. Il regrette qu'en raison de la guerre des Balkans il y ait si peu de ses compatriotes qui ont pu s'absenter mais quant à ceux qui ont eu le privilège d'être présents, dit-il, on peut être sûr qu'ils conserveront toujours un agréable souvenir de leur visite.

M. ARMAND RENIER représentant la Belgique où doit se tenir le prochain Congrès, s'étend longuement sur la belle réception que l'on a faite aux membres dans ce pays et, au milieu d'un grand enthousiasme, demande aux convives de boire à la "poudre des géologues."

M. CHAMBERLIN au nom du pays voisin félicite le Canada sur la bonne réussite du Congrès. Parlant de l'histoire géologique du Canada il prédit pour ce pays un brillant avenir. Le message mystérieux inspiré à l'humanité par la géologie paraît être, dit-il, un présage pour l'avenir, un présage des plus grandes destinées pour la race humaine et pour la race supérieure qui ne tardera peut-être pas à se développer. L'avenir répondra de ces destinées dont l'accomplissement se fera bientôt sentir, et l'orateur assigne au Canada l'un des premiers rôles dans ce glorieux avenir.

M. TERMIER représentant la France, fait ressortir dans un langage poétique les charmes de la géologie, soeur du temps, une science digne d'un grand poète, une déesse dont les disciples fidèles sont restés pauvres et modestes, bravant tous les dangers à son service. Il remercie tous ceux qui ont si bien travaillé pour faire de la Douzième Session un véritable succès.

M. AUBREY STRAHAN se déclare très impressionné non pas autant par la vaste étendue du Canada que par les capacités que les géologues canadiens ont déployées dans l'accomplissement de leurs travaux. Après avoir donné un aperçu des rapports entre la géologie industrielle, la géologie appliquée et la géologie purement scientifique, il insiste sur les relations étroites qui devraient exister entre le savant et l'industriel exploitant. Comme conclusion, il exprime au nom de ses collègues des Îles Britanniques toute sa reconnaissance aux membres du Comité, et les félicite du succès remarquable qui a couronné leurs efforts.

M. FERMOR représentant l'Inde, débute par ces paroles: "Président sahib, Mem sahib, aur sahib lagonko, Salaam!" faisant part ainsi des salutations de millions de compatriotes de cette vaste contrée du soleil. Il établit un contraste entre le développement minier de l'Inde, ce pays de civilisation si ancienne, et celui du Canada, tout à l'avantage de ce dernier pour le moment; mais il prévoit que son propre pays reprendra bientôt le temps perdu.

Le professeur DE STEFANI rappelle la liaison intime de l'Italie avec les débuts de l'historie du Canada: les noms de Colomb et de Cabot seront toujours chers aux deux pays. Il apporte de la vieille terre d'Italie ses compliments au Canada, pays de jeunesse, de force et de vigueur, destiné à un brillant avenir.

M. INOUYE, délégué du Japon, exprime tout le plaisir que lui et ses collègues ont éprouvé à se trouver au milieu de tant de géologues distingués de toutes les parties du monde; il parle de l'agrément que leur ont procuré les excursions du Congrès et dit que ces agréables journées passées au Canada sont de celles qu'on n'oublie jamais. De telles réunions constituent un puissant facteur pour relier plus étroitement les amitiés internationales. Il félicite le peuple canadien en lui disant: "Couryon spaijaba! Couryon spaijaba!

M. TSCHERNYSCHEW remercie le Comité exécutif, la ville de Toronto et le Canada entier pour l'aimable réception dont partout les membres ont été l'objet. De même que ses collègues de Russie, il s'est senti chez lui au

Canada; ils ont été frappés de la ressemblance des particularités géologiques et topographiques de ce pays avec celles de la Russie.

M. SJOGREN qui représente la Suède est très heureux que le Congrès ait eu l'avantage de se réunir au Canada; il est chargé par le président du dernier Congrès, le baron de Geer de transmettre ses plus cordiales salutations et de dire combien il regrette de n'avoir pu se rendre au Canada Les géologues européens ont très bien apprécié l'avantage qui leur a été donné d'étudier en Canada le noyau le plus considérable au monde de ces roches archéennes mystérieuses dont toutes les autres dérivent; c'est encourageant pour eux d'être témoin de la conquête scientifique du nouveau monde par la race anglo-saxonne, en collaboration avec les éléments nationaux les plus divers, formant un ensemble mixte, une ramification jeune et vigoureuse de l'arbre européen. Les géologues suédois sont particulièrement heureux d'assister à une réunion au Canada, cette terre sur laquelle les Scandinaves, dans un passé lontain, ont été les premiers hommes blancs à mettre le pied, ce pays avec lequel le leur a été relié par un pont géologique dont les piliers sont le Spitzberg, le Groënland et les îles Arctiques du Canada.

Le président propose ensuite la santé des dames au nom desquelles M. McDERMID répond en termes bien choisis. On a le plaisir d'entendre chanter à plusieurs reprises M. JAMES CAYLER BLACK entre les discours, et la fête se termine par le God save the King.

A LA MEMOIRE DE SIR WILLIAM LOGAN.

La pose de deux plaques dédiées à la mémoire de sir WILLIAM EDMOND LOGAN, fondateur et premier directeur de la Commission géologique du Canada, a constitué un incident notable en dehors du programme du Congrès. Ces plaques sont en bronze et fondues d'après le même modèle.

La première a été placée au village de Percé dans la Péninsule de Gaspé, Québec. Percé a été choisi comme l'emplacement le plus convenable parce que, en dehors du mesurage de la fameuse coupe de roches carbonifères à Joggins sud, Nouvelle-Ecosse, la Gaspésie a été le théâtre des premiers travaux géologiques de détail exécutés par LOGAN en Canada. La seconde plaque a été posée sur un énorme caillou de gneiss "Ottawa" (Laurentien), auprès de l'entrée du musée commémoratif Victoria, à Ottawa.

L'idée d'ériger à ce moment quelque souvenir convenable à la mémoire de LOGAN a été suscitée par le Dr. JOHN M. CLARKE d'Albany, qui, sur l'invitation spéciale du Dr. GEORGE M. DAWSON, avait été chargé de l'étude des formations géologiques de la Péninsule de Gaspé. Dès le début de ces examens, le Dr. CLARKE apprit à apprécier le travail géologique de Logan sur ce terrain vierge et à se fier à l'exactitude de la majeure partie de ses conclusions. La proposition courtoise et opportune du Dr. CLARKE qui était accompagnée d'une souscription très importante fut immédiatement adoptée par le comité exécutif, qui nomma un sous-comité spécial composé de MM. A. E. BARLOW, président, W. G. MILLER, R. W. BROCK et A. P. COLEMAN qui furent à même, grâce aux souscriptions généreuses des géologues canadiens, de mener à bonne fin le projet.

Le dessin de la plaque fut confié au jeune sculpteur canadien, M. HENRI HÉBERT de l'université McGill, qui a parfaitement réussi à réaliser l'idéal du comité; la tête qui ressort du bas relief est une création puissante et frappante. La ressemblance vivante s'impose à tous ceux qui ont eu le plaisir et l'avantage de connaître sir WILLIAM LOGAN.

La cérémonie du dévoilement de la première plaque a eu lieu durant la visite de l'Excursion A 1, au village de Percé dans l'après-midi du mercredi 16 juillet, en présence d'un grand assemblage de villageois heureux et intéressés, et de représentants de beaucoup des plus grandes institutions géologiques du monde.

Aucune cérémonie n'aurait pu avoir de cadre mieux choisi. D'un côté, se dressait la cime multicolore couronnée d'une croix du Mont Ste. Anne et de l'autre se dessinait le massif gigantesque de la Roche Percée, dont les falaises toutes coloriées renvoyaient sous les lueurs éblouissantes du soleil des teintes de rouge et de jaune rubanées de grandes côtes de blanc et de gris-bleu. Au centre où se dirigeaient tous les regards se trouvait la plaque—encore drapée sous les plis de l'Union Jack—fixée à la paroi septentrionale et polie d'un petit monticule rocheux, débris d'érosion, survivant du conflit des forces de la Nature.

Sur un des côtés, dans une position périlleuse, le long du flanc presque vertical du bloc rocheux se tenait Mademoiselle "Dolly" Tuzo, la charmante

Monument Logan à Ottawa.

enfant du shérif, le bras tendu et le visage souriant, s'apprêtant à exécuter le signal qui lui serait donné de découvrir à l'assistance la vue de la plaque.

Le Dr. BARLOW, en sa qualité de président du comité, expliqua brièvement l'origine et le but du Souvenir LOGAN, puis le Dr. CLARKE prononça un éloge éloquent de sir WILLIAM LOGAN et de son oeuvre particulièrement en ce qu'elle a trait à la péninsule de Gaspé. "Cette oeuvre," a-t-il dit, "a fait des falaises et des montagnes de Gaspé et de Percé le champ historique de la géologie canadienne. Rien ne peut rendre mieux, peut-être, l'attitude de tous ceux qui sont réunis ici aujourd'hui, que de répéter cette simple phrase qui embellit le blason de la province de Québec, 'Je me souviens.'" Le maire de Percé remercia avec beaucoup d'à-propos le Dr. CLARKE et les membres du comité du Souvenir LOGAN et accepta au nom du peuple de Percé la responsabilité de l'entretien de la plaque. La compagnie de pêche de Percé a gracieusement offert de transmettre au Directeur de la Commission géologique, en fidei-commis pour le peuple de Gaspé, le terrain sur lequel a été deposée la plaque.

Le dévoilement de la plaque posée à Ottawa a eu lieu vendredi aprèsmidi, le 1er août 1913, en présence de tous les géologues étrangers qui étaient arrivés au Canada à cette époque. M. JAMES WHITE, président du comité local présidait à la cérémonie. Une allocution a été prononcée par l'hon. T. W. CROTHERS, ministre du Travail qui, en l'absence du ministre des Mines, accepta au nom du gouvernement ce simple hommage au géologue canadien. Le Dr. ADAMS et le Dr. BARLOW parlèrent avec admiration de la grandeur et de l'importance pour le Canada de l'oeuve de ce pionnier de nos géologues. Sir WILLIAM mérite d'être appelé le premier et le plus grand des géologues canadiens. Aucun géologue avant ni après lui, n'a apprécié aussi intelligemment la valeur de l'étude scientifique de la géologie et n'a si bien compris l'application de ses principes à la mise en lumière des ressources minérales du Canada. Il comprenait parfaitement la dépendance mutuelle de la géologie pure et de la géologie appliquée et l'expression pratique qu'il savait donner à cette notion a eu un excellent effet pour faire apprécier et réaliser la valeur de ces ressources naturelles à l'extérieur comme à l'intérieur du Canada. Ses investigations géologiqûes dans un terrain vierge et spécialement son étude soigneuse et détaillée des ressources minérales du grand Bouclier canadien ont fermement établi le mérite durable des services qu'il a rendus à la science et à son pays.

CONFÉRENCES ET DISCUSSIONS PENDANT LA SESSION.

THE GEOLOGICAL MAP OF THE WORLD.[1]

BY

EMM. DE MARGERIE.

Mesdames, Messieurs:

Le 16 juin dernier, à ma grande surprise, je recevais du Secrétaire du Comité d'organisation de notre Congrès, un télégramme aussi conçu:

"Executive requests you deliver popular lecture in English at Congress to general public and members, and select subject. Cable."

Mon premier mouvement, je dois l'avouer, fut de refuser net. Pour un vieux routier des Congrès Internationaux comme votre serviteur, témoin, voilà juste trente-cinq ans de leur acte de naissance—tout se passait en français, dans ce temps-là—il était pénible, en abordant la terre canadienne, de remplacer la langue de CUVIER et D'ÉLIE DE BEAUMONT, qui fut aussi celle de CHAMPLAIN et de JACQUES CARTIER, par l'idiome de DARWIN et de Sir WILLIAM LOGAN. Puis, que choisir que fut intéresser à la fois le "general public" de Toronto et nos collègues, venus des quatre coins de la planète, sans risquer de fatiguer les uns par des détails trop techniques et d'ennuyer les autres par des developpements superflus, aux yeux des spécialistes?

Passant en revue les matières sur lesquelles il pourrait y avoir quelque chose à dire, l'idée me vint, tout à coup, que la *Carte géologique du Monde* n'était sans doute pas près d'etre achevée avant longtemps, et que, par conséquent, on permettrait peut-être à un géologue qui a beaucoup voyagé sur les cartes et dans les livres—beaucoup plus, hélas! qu'avec ses jambes—de parler de ce grand sujet, essentiellement "catholique" par definition, et donc, très digne d'etre exposé devant une assemblée internationale comme celle qui me fait l'honneur de m'écouter ce soir.

Excusez-moi, Messieurs les Anglais, si pour entrer en matière, j'ai cru devoir faire usage de ma langue maternelle. Et maintenant, vive SHAKSPEARE et le Roi GEORGE!

The attempts which have been made, so far, to represent the broad geological features of the globe on a single map can be reduced essentially to two: The *Essai de carte géologique du globe terrestre*, in one sheet, drawn by the French geologist, AMI BOUÉ, and published in Paris in 1845,[2] and the

[1] Public lecture given in Convocation Hall, University of Toronto, on August 7th 1913.

[2] A. BOUÉ, *Mémoire à l'appui d'un Essai de carte géologique du Globe terrestre présenté le 22 septembre 1843, à la Réunion des Naturalistes d'Allemagne à Gratz;* Bull. Soc. Géol. de France, 2e sér., I, 1843-1844, p. 296-371.

celebrated *Geological Map of the World*, in eight sheets, on the scale of 1:23,000,000, of which JULES MARCOU, another French savant of cosmopolitan fame, prepared two successive editions that were lithographed in Zürich in 1861 and 1873.[1]

MARCOU's map has been reproduced repeatedly on the same or a smaller scale in Switzerland, France, Germany, Austria and in England, from the hand of the author himself,[2] as well as by ÉLISÉE RECLUS,[3] OSCAR FRAAS,[4] H. WOODWARD,[5] ARTARIA,[6] J. M. ZIEGLER,[7] and JOSEPH PRESTWICH.[8] But, owing to the wonderful extent to which the study of regional Geology has been pushed in the last forty years, in nearly every quarter of the world, that map is no longer serviceable. Comparison with the more recent information which we now possess regarding China, the desert of Sahara or Alaska, for example,— countries where geological exploration had barely begun when MARCOU was delineating his planisphere,— shows this plainly.

The available material is now so vast that it would be quite impossible for a single man to undertake a graphical synthesis of the whole. Coöperation has become an absolute necessity; and this state of affairs amply justifies the action taken by the Stockholm Congress in giving the Commission of the International Map of Europe, enlarged by the addition of several representatives from the two Americas and Australia, charge of examining into this

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[1] JULES MARCOU, *Carte géologique de la Terre;* Bull. Soc. de Géogr., Paris, 5e sér., XI, 1866, janvier-juin, p. 509-514.

Sur ma seconde édition de la Carte géologique de la Terre; Ibid, 6e sér., V, 1873, janvier-juin, p. 631-640; translated into English in the American Naturalist, vol. VII, June, 1873, pp. 345-352.

[2] In the volume bearing the title: *Explication d'une seconde édition de la Carte géologique de la Terre;* 253 p., 1 pl., J. WURSTER & CIE, Zürich, 1875. That very useful summary, despite a somewhat peculiar style of writing and too many careless appreciations of the work of several geologists, marks a date in the history of descriptive geology. Professor EDUARD SUESS has already pointed out its importance; (*Das Antlitz der Erde*, Bd. 1. 8vo, Wien-Prag-Leipzig, 1885; p. 814 of the French translation, Paris, 1897).

[3] E. RECLUS, *La Terre, description des phénomènes de la vie du Globe, I. Les Continents*, 8vo, Paris, 1867, pl. II.

[4] O. FRAAS, *Vor der Sündfluth.* 8vo, Stuttgart, 1865.

[5] H. WOODWARD, *Geological Map of the World;* in the English translation of *The Earth*, by E. RECLUS, vol. I, pl. II, London, 1871.

[6] ARTARIA & CO., *Geologische Uebersichtskarte der Erde*, nach MARCOU, FRAAS, HEER, BOUÉ u. A., Wien, 1873, 1 sheet (published in the series of ARTARIA's, *Physikalische Karten*).

[7] J. M. ZIEGLER, *Ein geographischer Text zur geologischen Karte der Erde;* 1 vol. 8vo and 1 atlas 4to, Basel, 1883 (second edition, 1890), pl. 1: *Geologische Uebersicht der Erde;* nach J. MARCOU, mit Nachträgen.

[8] J. PRESTWICH, *Geology, Chemical, Physical, and Stratigraphical;* frontispiece, vol. I, Oxford, 1886. The author writes as follows, in his preliminary remarks: "The frontispiece Map of the World is a reduction from the large map constructed by Professor JULES MARCOU, to whom I am indebted for its revision; and I only regret that the small size of the reduction renders it impossible to do justice to the larger work" (p. viii). He then proceeds to enumerate the changes introduced into the original map of MARCOU in order to take advantage of the results of the most recent explorations.

"question of the Geological Map of the World."[1] I am not myself a member of that Commission, and as I have not been informed of the plans or resolutions which may have been taken on its behalf, I must declare at the beginning that I speak here purely on my own responsibility, my single object being to lay before the present Congress the conclusions to which I have been led by a protracted experi[illegible] in geological cartography.

Both AMI BOUÉ's essay and the larger maps of MARCOU were drawn on MERCATOR's projection. The inconveniences arising from the use of that mode of development are, however, so evident that, as early as 1886, HERMANN BERGHAUS, the eminent German cartographer, was induced to propose another device: the adoption of a separate centre of projection for each continental unit. The maps of Asia, Africa, North America, South America and of Oceania, on the uniform scale of 1 : 30,000,000, in his *Physikalischer Atlas*,[2] make up together, in reality, a third Geological Map of the World, and mark a great advance on the planisphere of 1873.[3]

Let us now consider somewhat more closely the drawbacks of MERCATOR's projection. There is, first, the systematic deformation of surface, that grows larger and larger as the poles are approached and makes any comparison of countries of different latitudes impracticable; moreover, and as a consequence, certain features which, in reality, make a greater or lesser angle upon the sphere appear to be parallel to each other. Furthe[r],—and this fact results from the trend of human history,— as the temperate zone is, generally speaking, the best known section of the earth's surface geologically, it so happens that MERCATOR's projection exaggerates the apparent areas covered by land and sea *[inv]ersely to the actual extent of our present knowledge,* the exaggeration reaching a maximum around the poles, where that know-

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[1] Congrès Géologique International, *Compte Rendu de la XIe Session*, Stockholm, 1910, fasc I, p. 89-91, 115, and 153-156. The text of the resolution approved by the Congress reads as follows: "Le Conseil décide que MM. BROCK (Canada), SMITH et WILLIS (États-Unis), AGUILERA (Mexique), KEIDEL (Argentine), et DAVID (Australie) seront adjoints à la Commission de la Carte géologique de l'Europe pour préparer la question de la Carte géologique mondiale. Dans cette Commission ainsi complétée, MM. BEYSCHLAG, CAPELLINI, G. O. SMITH, SUESS, TEALL et TSCHERNYSCHEW sont chargés de présenter à la prochaine session du Congrès un programme detaillé de cette Carte géologique du globe" (p. 90). It is worthy of remark that nobody in that Commission represents Asia and Africa, and that the French colonies notably have no official delegates among its members. Should not representatives of the Geological Surveys of British India, of French Indo-China, of Japan, Egypt, Algeria and South Africa be included in it?

[2] Abteilung 1, *Atlas der Geologie*, Gotha, Justus Perthes, 1892. These maps bear the following numbers: XI. Asien und Europa (Entw. 1887, Ausg. 1889); XII. Afrika (1887, 1888); XIII. Nord-Amerika (1886, 1887); XIV. Süd-Amerika (1891); XV. Oceanien (1886, 1888). Except No. XIV, which bears the record: "Bearb. v. G. STEINMANN u. HERM. BERGHAUS. Red. v. R. LUEDDECKE," they are exclusively the work of BERGHAUS.

[3] As such may be designated, in BERGHAUS' *Atlas*, the recapitulating map bearing Nos. VII and VIII: "*Übersicht der Erde*. Bearbeitet von Dr. R. LUEDDECKE und Dr. C. ROHRBACH, Ausgabe 1892." That map has been used as a basis for the planimetric calculations of the Russian General, ALEXIS DE TILLO: *Superficies absolues et répartition relative des terrains occupés par les principaux groupes géo[lo]giques* (C. R. Acad. Sc., Paris, CXIV, 1894, 1er sem., p. 246-248); and *Répartition d[illegible] [oc]cupés par les groupes géologiques d'après les longitudes et les latitudes terrestres* [illegible] [9]67-970).

ledge diminishes to nothing. Such a consideration ought not to be disregarded when the matter is considered from a financial standpoint.

In order to reduce in a certain measure the fault which has just been pointed out, it has sometimes been suggested that for similar undertakings, a composite plan, involving the use of MERCATOR's projection for low and mean latitudes and a gnomonic development for the two polar caps, should be adopted, the pole for each corresponding hemisphere being made an independent centre of projection. Such is the device adopted, for example, on the beautiful *Bathymetric Map of the Oceans*, prepared through the munificence of H.S.H. the PRINCE OF MONACO, and the origin of which is also, partly at least, international.[1] But the several sheets cannot be assembled to form a unit; hence this compromise, as regards the Geological Map of World, does not really constitute a solution of the problem.

Before proceeding farther, it seems appropriate to review the contri- ons existing at present which may render our task easier.

1. There exists an International Geological Map of Europe, on the scale of 1:1,500,000, in 49 sheets, nearly all of which are now printed.[2] It will remain a source of glory for the second of our International Geological Congresses, held in Bologna in 1881, to have decided upon the preparation of that fine map and a source of honour for the principal governments of Europe to have made its publication possible by their financial support The execution of the Map of Europe must certainly be looked upon as t. most important of the material results yet obtained through the initiati of our Congresses—without wishing to deprecate in the least the value of suc. international enquiries as the two works on *The Iron Ore Resources of the World*[3] and *The Coal Resources of the World*,[4] which undoubtedly will be considered, in the future, as the most valuable outcome of the last and the present sessions.

So far as Europe is concerned, then, if we leave out of consideration a few secondary points, such as the correction of details, scale of reduction, simplification of the legend, etc., the work, in its broader aspects, is done; there remains no capital problem to be solved, and the difficulties which may arise are more graphical and commercial than purely scientific in nature.

The experience gained in preparing that Geological Map of Europe, both as regards its elaboration and its publication, has shown that it would be utterly impracticable, at the present time, to extend such a large scale to other parts of the globe—not to speak of the scale of 1:1,000,000, which is rapidly becoming the standard scale for purely geo-

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[1] That map, prepared in accordance with the votes polled at a conference held in Wiesbaden (1903), comprises 24 sheets on the scale of 1 : 10,000,000 at the equator. A second edition, in which the hypsometry of the lands has been added, and which has been modified in many details, following the rules adopted in Monaco (1910), is now in course of publication in Paris.

[2] In course of publication in Berlin since 1894.

[3] 2 vols. 4to and an Atlas folio, Stockholm, 1910.

[4] 3 vols. gr. 8vo and an Atlas folio, Toronto, 1913.

graphical purposes the world over, according to the plan originated more than twenty years ago by Professor PENCK.[1] That scale of 1:1,000,000, submitted in 1910 by Dr. G. O. SMITH, Director of the United States Geological Survey, for the approval of the Stockholm Congress as the scale for the future Geological Map of the World, was unanimously rejected, as you know, without regard for future conditions.[2]

And let us remark in this connection, that events seem to turn out for the Map of the World in just the same way as happened for Europe, where collective and international action was preceded long before by the undertaking of an individual: I allude now to the fine Geological Map of Europe of the great Belgian stratigrapher ANDRÉ DUMONT, in four sheets, on the scale of 1:3,000,000, engraved and printed in Paris at the "Imprimerie Impériale" in 1857.[3]

2. Another case commends itself very strongly to our attention; and it seems the more proper to speak of it, at the present time, that it was also connected, at least in the first stages of its development, with the work of our Congresses. I refer to the *Geological Map of North America*, originally prepared at the suggestion of the United States Geological Survey, and executed, with the cooperation of the Geological Survey of Canada and the Geological Survey of Mexico, by our friend BAILEY WILLIS,[4] for the session held in Mexico City in 1906. A second edition of that map, entirely recast, was published in 1911;[5] it enjoys the distinction of being, among all the geological maps in existence, the one of which the largest edition has probably ever been printed, no less than 13,700 copies of each of its four sheets having been struck from the press in Washington, requiring altogether, with their 70 colour plates, more than a million separate impressions.[6]

Mr. WILLIS has given with his map, by way of an explanatory text, a voluminous *Index to the Stratigraphy of North America*,[7] which constitutes

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[1] For the present state of that great undertaking, so far as North America is concerned, see W. L. G. JOERG, *Development and State of Progress of the United States Portion of the International Map of the World*; Bull. Amer. Geogr. Soc., New York, vol., XLIV, 1912, p. 838-843, map.

[2] *Proposition du Service Géologique des États-Unis de l'Amérique du Nord, concernant la création d'une Carte géologique mondiale sur l'échelle 1:1,000,000*; Congrès Géol. Internat., *C. R. de la XIe Session*, Stockholm, 1910, 1er fasc., p. 164-186.

[3] A reduction slightly simplified, in one sheet, of DUMONT's map was published in Brussels, in 1875, by Capt. HENNEQUIN.

[4] *Carte géologique de l'Amérique du Nord.* Dressée, d'après les sources officielles des États-Unis, du Canada et de la République du Mexique. HENRY GANNETT, géographe; BAILEY WILLIS, géologue. For a critical review of that remarkable map, see EMM. DE MARGERIE, Annales de Géographie, 1908, XVII, p. 56-70.

[5] *Geologic Map of North America compiled by the United States Geological Survey in cooperation with the Geological Survey of Canada and the Instituto Geologico de Mexico under the supervision of* BAILEY WILLIS *and* GEORGE W. STOSE.

[6] 1,098,000 separate impressions for the total edition of the map; U. S. Geol. Survey, Press Bulletin, New Series, No. 15, September 4th-7th, 1911.

[7] United States Geological Survey, Professional Paper No. 71, 4to, 894 p., 19 maps in the text and five tables, Washington, 1912; includes, p. 840-865, a Bibliographic List of 953 references.

another wonderful monument of his skill and energy, and deserves in the fullest sense the grateful recognition of geologists the world over.

Here again, then, we have first-rate material, which will certainly stand the test of time for many years. For that quarter of the globe, all that needs now to be done is of the nature of trifling emendations and compilation.

From what I have said, it follows that the most energetic efforts must hereafter be directed towards the continental masses which have not been made, as yet, the subject of a similar undertaking, that is, Asia and the neighbouring islands, Africa, South America, and Australia. And I now come immediately to the plan which it is my intention to develop: *to prepare geological maps of those continents, each with its own projection centre, drawn on a uniform scale of 1:5,000,000, and following broadly the lines of the Geological Map of North America.*

I must now state the advantages of such a plan and give some hints as to how, in a practical way, it would be possible to begin its realization.

Useless as it seems to come back again to the subject of projective deformations, perhaps something still remains to be said, in that connection, from a financial point of view. Operating on the same map-scale, what I would call the "continental system" permits, necessarily, a very important economy of area, of paper, and ultimately of money, as compared with the "world system." As the ocean covers—everyone is aware of the fact—about seven-tenths of the earth's surface,[1] and as the geology of its bed below the sediments in process of deposition remains absolutely unknown and, for the present at least, inaccessible to our means of investigation,[2] it seems proper to include in geological maps only what is necessary of marine areas to frame in the lands. A continuous map, on the scale of 1:5,000,000 at the equator, would give four times as many sheets as the Bathymetric Map of the PRINCE OF MONACO, which is on the scale of 1:10,000,000, that is, 96 instead of 24. Separate maps, drawn upon the same scale and representing the four continents alluded to above, would give a total of 16 sheets only,—six times less,—distributed thus: Asia, 6; Africa, 4; South America, 4; Australia, 2.

Those four maps being independent of each other, there would be ro moral objection and many practical advantages te begin their elaboration in different places and through different hands,—as regards division of

[1] Exactly 0.717 according to the most recent calculations of Professor A. BERGET, (*La répartition géographique des Océans et la détermination du Pôle continental;* Annales de l'Institut Océanographique, Paris. V, No. 9, 1913, p. 3).

[2] As is well known, precise knowledge regarding the geological nature of the sea-bottom can be gathered only under very exceptional conditions; such was the case when soundings were made in the Straits of Dover, about forty years ago, by POTIER and DE LAPPARENT, as a preliminary step to the establishment of a submarine tunnel between England and the Continent; see Comptes Rendus Acad. Sc., Paris, LXXXIV, 1877, p. 1331. For other examples, see a paper by PAUL LEMOINE, *La géologie du fond des mers;* Annales de Géogr., XXI, 1912, p. 385-392, fig. 1, 2. The famous work of DELESSE on the lithology of the principal seas of the globe, considers only the formations which are being accumulated on the sea-bottom at the present time.

expense between the people most directly interested, as well as the construction of the legend or the determination of the colour scheme.

In that connection, a comparison between the International Map of Europe and the Map of North America is highly suggestive; although the aim followed and the general conditions of the work were strictly similar on both sides, neither the divisions of the time scale nor even the major features of the colour scheme are identical. If, then, it has not been found practicable, for the most competent experts in the two continents of which the geology is by far the best known, to come to a unanimous accord, one can guess at the difficulties which the same undertaking would encounter in other parts of the earth's surface, where rock formations differ much more widely from those of classical districts than is the case in the United States or in Canada. It is true that ideas have changed since twenty-five years ago, when, on the occasion of the Congress held in London, Mr. G. K. Gilbert protested against the tyranny of a nomenclature pretending to universal application, by formulating the principle that stratigraphic series are essentially *local* in character;[1] more recent studies tend to show everywhere, on the contrary, that breaks between successive faunas and groups of strata are remarkably constant over enormous areas. But, without taking exception to the harmonious development of organic life upon the globe, it seems equally necessary, from a practical point of view at least, to take into account the discrepancies, sometimes very marked, which give to the geology of each part of the earth's surface its individual characteristics. The same scheme, for example, cannot be adopted for the African continent, where marine deposits, as in Australia, come to an end before the close of Palæozoic time and reappear sporadically at a very late period, and for the great folded mountain ranges of southern Europe and Asia, where Mesozoic strata show an extraordinary thickness and a wonderful variety of fossils. Why, then, for the sake of merely ideal uniformity,—for the maps of those contrasting regions are not intended to be placed side by side,—govern the use of certain colours by inflexible rules that exclude the possibility of adjustment, both in respect to the general effect upon the eye and to eventual emergencies of an economic nature?

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[1] G. K. Gilbert, *The Work of the International Congress of Geologists*; Amer. Journ. Sc., 3rd Ser., Vol. XXXIV, 1887, p. 430-451; Abstract by Emm. de Margerie, under the title: *L'œuvre du Congrès Géologique International*; Bull. Soc. Géol. de France, 3e sér., XVI, 1887-88, p. 2-7. In the opinion of most of the European stratigraphers, the reaction against attempts at premature correlations implied by the exclusive use of systematic (stage) names has been pushed too far in the United States, resulting in a somewhat confusing and useless multiplication of local formation names. At any rate, terrains that long ago received proper designations in the world scale should not get new ones for the sake of nationalism—such as *Comanchean* replacing "Lower Cretaceous" on the map of North America. Again, despite the rules of priority, a name coined with a definite sense should not be moved to another place in the geological column so as to assume a significance entirely different from that assigned by its originator, e.g. the term *Mississippian*, proposed in 1858 by Marcou for the Cambrian (see his *Lettres sur les roches du Jura*, 8vo, 1858, p. 209, 212), and appearing on Willis' map as an equivalent of "Upper Carboniferous." But this point is not of direct interest for the Map of the World; the special committee appointed to report on the plan of a Stratigraphical Lexicon, elaborated by Dr. L. Waagen, will certainly utter authoritative opinions on this very important matter.

However it may be, the future Geological Map of the World, drawn either on the "continental system" or on the "world system," although based essentially, of course, on the distinction of the great stratigraphic units, must take account, in a large measure, of a double trend which is permeating more and more the spirit of research and finds its expression in what has been called *palæogeography* on one side and *tectonics* on the other. It is desirable to discriminate by means of appropriate symbols: (1) freshwater or subaerial deposits from those which are of marine origin; (2) districts where the strata have remained undisturbed from regions where they are more or less intensely folded.

No doubt, the separate colouring of marine and of land *facies* on maps is often a matter of considerable difficulty; still, it well repays the effort made to differentiate at least the broad areas of subaerial or lacustrine sediments, as the late ALBERT DE LAPPARENT seems to have been the first to do in his small map of the Paris basin,[1] and as AUGUSTE MICHEL-LÉVY and his colleagues have extended it more recently, to the whole territory of France.[2]

That such an attempt, generalized for an entire continent, can really be undertaken is proved beyond dispute by the enormous extent of such freshwater formations as the "Gondwana system" of the southern hemisphere or of the Tertiary beds, so rich in mammalian remains, of the interior of the United States. These continental accumulations could easily be distinguished from ordinary marine sediments by patterns, replacing the full colours restricted to normal deposits; black hachures, such as are used on the French maps, have the bad effect, especially when the scale of the map is small, of obscuring the lettering and spoiling the general appearance of the colours.

The discrimination between undisturbed and folded rock series is not less important for a full understanding of the past history of the continents and of their present structure, and it may probably be depicted more easily than the preceding features, because orogenic processes generally affect areas more uniformly as well as more extensively. Here, again, we have a very remarkable model, which, unfortunately, is still in a manuscript state and which I regret not to be able to exhibit on this occasion: the Structural Map of Asia, on the scale of 1:7,000,000, executed by a young Swiss geologist, ÉMILE ARGAND. The method of colouring of that kind of map was set forth by CLARENCE KING as early as 1878, in the first volume of his *Geological Exploration of the Fortieth Parallel*.[3] The colour scheme is the

[1] Map accompanying his book: *La Géologie en chemin de fer. Description géologique du Bassin Parisien;* 8vo, Paris, 1883. Scale 1: 2,500,000. Plain colours are restricted to formations of purely marine origin; continental formations are shown by oblique hachures, and those of a mixed nature by horizontal lines.

[2] *Carte géologique de la France à l'échelle du millionième.* 2nd ed., 4 sheets, Paris, 1906. See also the sheets of the general Geological Map of France on the scale of 1:320,000, in course of publication.

[3] *Systematic Geology;* 4to, Washington. See, p. 760, the "Analytical Geological Maps" VIII-XII, whose object is defined by their sub-title: *Exposures of Successive Orographic Disturbances.*

same as on ordinary geological maps; but, instead of using it according to the age of the strata themselves, recourse is taken to the date of the disturbances which are responsible for their present attitude. The brilliant professor of Neuchatel has gone a step farther: in order to show not only the outcrops of the folded terranes, but also the real extent over which earth-movements have operated, he has coloured in paler tints the undisturbed formations of corresponding age. Perhaps that method is to be preferred to KING's, as it is more synoptic in its results and, at the same time, easier to couple with the usual object of geological maps.

Of course, it would be equally interesting to depict with the aid of appropriate symbols—according to the examples given by the 1: 1,000,000 Geological Map of France[1] or by the fine map of Württemberg drawn by Dr. C. REGELMANN[2]—the major tectonic axes or lines, the presence of which do not sufficiently appear on first view from the reading of geological boundaries, e.g., the great normal faults of plateau-like countries, the thrust-planes of folded districts, etc. One cannot conceive of a geological map of Africa where the *graben* or "rift valleys," so characteristic of the lake region, would not be indicated; nor a map of Asia upon which no particular sign would localize the huge overthrust faults of Tibet or of Yun-Nan.

A last feature ought not to be omitted: the equatorial limit of the Pleistocene ice-sheets; that important boundary, which is so full of applications, especially from the physiographer's standpoint, is marked on the International Map of Europe by a red line.[3]

It is not my purpose, in this brief review, to discuss again the question of the colour scheme. All has been said already on that subject in the earlier sessions of the Congress, and much can be gleaned from their Transactions.[4] There remains however, a point which it does not seem superfluous to emphasize, as the *Geological Map of North America*, so favourably quoted above, appears, at first sight, contradictory to that desideratum: the necessity of using exclusively *plain colours or monochromatic patterns*. I have no hesitation in asserting and this view held unanimously, I believe, by experts, in Europe at least,—that the practice of overprinting patterns of another tone on a certain plain colour must be entirely rejected; likewise the method which combines discontinuous patterns with the effect of the paper on which the map is printed, when those patterns are large enough to be seen with the naked eye. In that respect, the second edition of Mr. WILLIS' map marks

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[1] See EMM. DE MARGERIE, *La nouvelle édition de la Carte Géologique de la France à l'échelle du millionième;* Annales de Géogr., XV, 1906, p. 168-172.

[2] *Geognostische Übersichtskarte von Württemberg und Baden, dem Elsass und der Pfalz*, 1: 600,000. The first edition of this map bears the date 1893; in twenty years, no less than *eight* successive editions have been published, each one marking a decided improvement upon the preceding.

[3] This method was used, as early as 1849, by ANDRÉ DUMONT, in his geological map of Belgium.

[4] See especially the Proceedings of the three first sessions: Paris (I, 1878), Bologna (II, 1881), and Berlin (III, 1885).

a decided step backwards, as compared with the first:[1] the ten different patterns representing Algonkian, Archean, and Metamorphic formations are rather unhappy substitutes, as to clearness, for the good, frank, plain colours employed in the original publication. A certain symbolism, no doubt, is at the root of the colouring of geological maps: and such is the meaning of the small spots irregularly distributed over a colour base,—a device which reminds somewhat of the large feldspar phenocrysts in a porphyritic granite.[2] It is certainly commendable for illustrations printed in black, and I have often followed it myself in the sketch maps of the French edition of *The Face of the Earth*, for example.[3] But when colours are at command, such a practice looks rather childish and obsolete.

I would say the same of the attempt made by W. J. McGee, in his Geological Map of the United States published in 1893,[5] to suggest the detrital origin of the glacial drift by small black dots printed over the formation colours that represent the terranes *in situ*; the only result is to render that part of the map utterly illegible. Clearly, a person unfamiliar with such elementary notions could not interpret a geological map: that helpful symbolism, then, overshoots the mark.

It is unnecessary to remark that my criticisms against patterns and overprinting processes apply exclusively, in my mind, to small-scale maps. For maps on a large scale, on the contrary, the example of the beautiful folios of the *Geologic Atlas of the United States* shows what really remarkable results may be expected, without speaking of the evident economy allowed in the number of printings, and, consequently, in the total cost of publication.

We have, so far, briefly reviewed the efforts made up to the present time to construct a Geological Map of the World, enumerating the obstacles of various kinds which have been encountered. We have also formulated incidentally, the main desiderata of a palæogeographic, of a tectonic, and of a practical nature which ought not to be lost sight of in the preparation of a new map. We must now consider together the ways and means by which such a map could be, if possible, prepared in the near future.

As opposed to the "world system," what I have called the "continental system" implies a division of labor, not only in the collection and coördination of scientific results, but also in the actual execution of the work. Taking into account present conditions as a matter of course, I have the honour to submit to the consideration of the Congress the following plan:

1. As we are in America, let us begin, first, with that double continent:

[1] Nos. 20, 21, 21b, 22, 22b, 23, 23a, 23b, 23c, 23d of the Legend.

[2] On the symbolic origin of the colours adopted for the colouring of geological maps, see Ami Boué, *Guide du géologue-voyageur*, 2 vols. in - 18, I, Paris, 1835, p. 148.

[3] See especially Vol. III, Parts 1, 2 and 3. 8vo, Paris, 1902, 1910, 1913.

[4] *Reconnaissance Map of the United States, showing the Distribution of the Geologic Systems so far as known*; compiled from data in the possession of the United States Geological Survey by W. J. McGee (accompanies the 14th Annual Report of the U.S.G.S., 1892-93, pt. 2).

North America, together with the West Indies, having already been provided for, it remains to discuss the interests of South America alone (4 sheets). Since the days when DARWIN and D'ORBIGNY made their memorable expeditions to the lands of the Rio de la Plata and the Andes, the most numerous and important papers dealing with the structure and history of those mountains have certainly been contributed by German geologists.[1]

Our colleague, Professor G. STEINMANN, of Bonn, has not only set an example of energetic and most successful work through his extensive explorations in Chile, Bolivia and Peru, but he has promoted in a most efficient manner the development of South American geology through the publication of numerous monographs of a palæontologic and stratigraphic character devoted by his pupils to the study of material brought home from the Cordilleras.[2] To Professor STEINMANN should belong the task of constructing the future geological map of that part of the world, a task which he apparently had in view in 1891, when he published the small sketch of South America which bears his name in BERGHAUS' *Physikalischer Atlas*. Among living geologists, he is the only one who may claim to know "*aus eigener Anschauung*" a great portion of that domain; nobody else is as familiar as he is with the varied faunas, with the representatives of which he has enriched German museums.

The Geological Survey of Buenos Aires, which is mostly in the hands of German geologists, will certainly agree to communicate to Professor STEINMANN its manuscript records, and there is no doubt that its example will be followed by the Geological Survey of Brazil, as well as by our friend Dr. BRANNER. It would remain, then, to find a publisher; one of the numerous flourishing cartographic establishments in the German Empire, such as the firms of JUSTUS PERTHES in Gotha, GIESECKE DEVRIENT in Leipzig, L. FRIEDRICHSEN in Hamburg, or the BERLINER LITHOGRAPHISCHES INSTITUT, seem to be especially fitted for the achievement of such an undertaking.

2. In continuing our survey of the southern hemisphere, we now come to Australia (2 sheets). Being a colony of Great Britain, Australia has at work in its territory at least four or five official geological surveys. It would seem proper, then, for these government institutions to combine their efforts in preparing, at common expense, the desired map. The scientific prepara-

[1] For a historical review of part of those explorations, see a memoir by Dr. H. STEFFEN: *Der Anteil der Deutschen an der geographischen und geologischen Erforschung der Republik Chile während der ersten Jahrhunderts ihre Bestehens;* Sonderabdruck aus: *Festschrift des Deutschen Wissensch ftlichen Vereines zu Santiago zur Zentenarfeier der Republik Chile.* 8vo, 60 p. Santiago de Chile, 1910.

[2] These contributions, collected under the title of *Beiträge zur Geologie und Palaeontologie von Süd-Amerika*, and of which Prof. STEINMANN is the editor, have been published at irregular intervals since 1892 in the supplementary volumes of the Neues Jahrbuch für Mineralogie, Geologie und Paläontologie (Stuttgart). In twenty years, no less than eighteen monographs have appeared; they are the work of seventeen different authors, and treat of the most varied members of the stratigraphical column, from Cambrian to Tertiary; all but one concern Andine regions.

tion of the work should be done either in Sydney or in Melbourne. The means at the disposal of the Commonwealth, financially and industrially, easily permit its final production in print without any aid from Europe.

3. Proceeding to Africa, we meet with more complex conditions. Geologic work in that continent is prosecuted simultaneously by local surveys (Algeria, Cape Colony, Egypt, etc.) and by metropolitan powers (Belgium, France, Germany, Italy, etc.), not to mention investigations pursued at private expense by explorers of different nationalities. But, in the same measure as European investigation and colonial development progress, the outcome of scientific research tends to become more and more centralized and better coördinated.

I bring before you a palpable proof of this fact: we have begun, in the office of the Geological Survey of France, to combine on a map all geological data available concerning the French possessions in northern, western and equatorial Africa. The preliminary draft, which I have the honour to exhibit on this occasion, is compiled precisely on the standard scale of 1: 5,000,000 and summarizes our present knowledge regarding the geology of Tunisia, Algeria, Morocco and northern Sahara. It has been obtained by reducing and generalizing the boundaries given by a number of original maps published by the *Service de la Carte Géologique de l'Algerie* and by Messrs. AUBERT, BLAYAC, FLAMAND, GENTIL, JOLEAUD and PERVINQUIÈRE.[1] We intend, next winter, to extend this map southwards so as to include all Mauretania, western and central Sahara, Senegambia, Guinea, the French Soudan and the British or German possessions (Nigeria, Togo, Cameroons), as far as the Gaboon and the equator. Numerous tracings, largely unpublished, from Messrs. CHUDEAU, GAUTIER, HUBERT, LACROIX, LEMOINE, etc., will allow most of the spaces left in blank on existing maps to be filled in. Work has also begun for the great island of Madagascar.

The delineation of geologic boundaries then, for a good fourth or third of Africa, is only a question of time, and France is willing to do it. In Egypt the Survey Department published, three years ago, two very fine maps of the whole country, on the scales of 1: 1,000,000 and 1: 2,000,000. Their reduction to 1: 5,000,000, including some corrections introduced in the meantime, is an unimportant labour. In the Belgian Congo, Professor CORNET is busy with the compilation of a map on which material from the five hundred or more memoirs and reports of which he has catalogued the titles will be

[1] The original maps consulted are the following: *Carte géologique de l'Algerie*, 1: 500,000, 4 sheets (3rd ed., 1900); *Carte géologique provisoire de la Tunisie*, par L. AUBERT, 1: 800,000, 1 sheet, 1892; *Carte géologique de la Tunisie centrale*, par L. PERVINQUIÈRE, 1: 200,000, 1 sheet, 1903; *Esquisse géologique de l'Extrême-Sud Tunisien*, par L. PERVINQUIÈRE, 1: 3,000,000 (Bull. Soc. Géol. de France, 4e sér., XII, 1912, p. 144); *Carte géologique du Sud Oranais*, par G. B. M. FLAMAND, 1: 800,000, 1 sheet, 1911; *Essai d'une Carte géologique du Maroc* par L. GENTIL 1: 2,500,000 (Annales de Géogr., XXII, 1912, pl. II); *Carte géologique d Bassin de la Seybouse et de quelques régions voisines*, par J. BLAYAC, 1: 300,000, 1912; *Car géologique d'une partie des régions de Constantine et de Philippeville*, par L. JOLEAU 1: 200,000, 1912.

graphically summarized.[1] In Cape Colony and Transvaal excellent geological maps on a large scale are not wanting; likewise reconnaissance sketches covering wide areas. In the German and Italian colonies, too, good preliminary maps already show at least the broader features of the country. French geologists, if the Congress considers it proper, would gladly take charge of the compilation of that scattered material and of editing a general map of the African continent, of which a French firm is willing to undertake the publication at its own risk.

4. We have still to examine the weightiest portion of the whole plan, that concerning Asia (6 sheets). It seems natural here to turn to our British and Russian colleagues, in the first place because of the political interests and of the territorial possessions which their respective countries possess in this the prototype of all continents. In other words, it is highly desirable that the Geological Surveys working in Calcutta and in St. Petersburg should furnish the tracings of those parts of Asia that are more or less directly under British or Russian influence—the Caucasus, Siberia, Turkestan and Mongolia on one side; India, Arabia, Baluchistan, Afghanistan, Tibet, Burma and western Indo-China on the other. The Geological Survey of Japan could also furnish valuable data on the east, likewise the Dutch Bureau of Mines for Borneo, western New Guinea and the Malay Islands, and the Geological Survey of French Indo-China for the eastern part of that peninsula and the adjoining parts of China. Western Asia is already shown on the last printed sheets of the International Map of Europe, where geological boundaries have been traced by Drs. BERG and BLANCKENHORN:[2] it would be sufficient simply to reduce most of these tracings to the smaller scale. As to Persia, published literature concerning its geology is rather meagre, and does not come seriously into account.

A single gap remains towards the east, but surely a very important one: China, with her eighteen provinces. No official institution is at work there; all the knowledge gathered so far is the outcome of private explorations, equipped by European or American individuals, and having as their object the reconnaissance of mere itineraries, more or less developed and more or less distant from each other. RICHTHOFEN, LÓCZY, OBRUTCHOV, LECLÈRE, LANTENOIS, BAILEY WILLIS, ABENDANON, TAFEL, such are the names of these pioneers. The critical discussion and comparison of the data which they have brought back should be entrusted to a competent geologist sufficiently familiar with the Far East; or else to the two associates who have so ably brought to a close the work of Baron RICHTHOFEN[3], the foremost among these explorers, Drs. TIESSEN and GROLL.

[1] A manuscript sketch of this map may be seen at the Colonial Museum in Tervueren.

[2] G. BERG, *Die Internationale Geologische Karte von Europa;* Petermanns Mitteil., Bd. LVII, 1911 (1) p. 201;

Die Darstellung Anatoliens auf der Internationalen Geologischen Karte von Europa; Ibid., Bd. LVII, 1911 (2), p. 213-215.

[3] F. Freiherr VON RICHTHOFEN, *China, Ergebnisse eigener Reisen und darauf gegründeter Studien.* Bd. III und V, 4to, Berlin, 1911-1912; Atlas, 2. Teil, folio.

Now, who will take charge of the engraving and publishing of the future Geological Map of Asia? In my opinion, that map ought to be executed in Great Britain; the work should tempt such an accomplished cartographer as Dr. J. G. BARTHOLOMEW, the head of the celebrated Edinburgh firm, who has given to the geographic world, for the last two or three scores of years, so many masterpieces in the art of map-making and colour-printing.[1] As to the cost, which certainly would be rather heavy, it could be covered in part by public subscription and in part by support from the government organizations operating in the countries represented on the map (British India, Russian Empire, Japan, Dutch East Indies, French Indo-China).

5. Let it be imagined that the programme sketched above has been carried out, and that the four continental masses: South America, Australia, Africa and Asia, have now each their independent geological map, on the uniform scale of 1: 5,000,000. A few gaps remain, which may be filled at small cost: the Antarctic continent and a few groups of islands lost in the midst of the ocean.

For the present, there is no necessity of delineating on a large scale the geology of the zone surrounding the South pole, for the double reason that by far the greater part of its surface is deeply buried under snow and ice and that our knowledge of the rocks protruding here and there from that glacial cap is still merely in its infancy.[2] For a long time to come, special maps such as those given by H. T. FERRAR[3] for South Victoria Land and J. G. ANDERSSON[4] for Graham Land, will be sufficient to supplement the information conveyed by ordinary geographical tracings; it seems useless to cause unnessary expense in that connection.

The same view holds good for the islands of Oceania, which are too small, in most cases, to be marked on general maps otherwise than by their name and their position. Look, for example, at the beautiful map showing the distribution of coral-reefs, published last year in Paris under the auspices of the Prince of MONACO, by Professor JOUBIN.[5] It consists of five large sheets, on the scale of 1: 10,000,000. If the rocks constituting these islands were more varied than they are, the delineation of geological details would be quite impossible for the great majority of them. On the other hand, the

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[1] Among the most widely known are: the *Atlas of Scotland*, the *Climatological Atlas of India* (ELLIOTT), the *Atlas of Meteorology*, the *Atlas of the World's Commerce*, the maps accompanying Sir JOHN MURRAY's and Sir ARCHIBALD GEIKIE's volumes, etc.

[2] See, in the Proceedings of the Stockholm Congress, the paper of R. E. PRIESTLEY and T. W. EDGEWORTH DAVID: *Geological Notes of the British Antarctic Expedition, 1907-09* (Vol. II, p. 767-811, 13 figs.), and the recent monograph by Prof. O. NORDENSKJOLD on the geology of American Antarctica (*Wissenschaftliche Ergebnisse der schwedischen Sud-polar-Expedition, 1901-1903*. Bd. I, Liefg. 1, Stockholm, 1911, p. 83-114: "*Geologie des Gebietes.*"

[3] *National Antarctic Expedition, 1901-1906*. *Natural History*. Vol. I, *Geology*. 4to, London, 1907. Map at end of volume.

[4] *On the Geology of Graham Land* (Bull. Geol. Institution Univ. of Upsala, Vol. VII, 1904-05, pl. 4, 1906).

[5] Annales de l'Institut Océanographique, Paris, IV, fasc. 2, 5 sheets folio, scale 1:10,000,000, 1912.

larger groups, in so far as they do not fall in the frame of the continental maps already planned, such as New Zealand, the Fiji Islands and New Caledonia,—of which I have brought here a manuscript map surveyed by a French geologist, Monsieur PIROUTET,—could easily be represented on inserts engraved on the margins of the map of Australia.

And now, I must conclude. To do so, let me use once more my mother language.

J'ai voulu montrer, dans les pages précédentes, qu'il n'est pas chimérique de prétendre que, d'ici à un petit nombre d'années, grace à une division du travail judicieusement établie, les professeurs et les hommes d'étude pourraient avoir entre les mains des cartes géologiques des grandes divisions de la Terre, strictement comparables entre elles comme échelle et comme tendances directrices, si non comme details d'exécution. Il faudrait seulement, pour arriver à un resultat aussi désirable, de la methode, un peu d'argent, et beaucoup de bonne volonté. Je m'estimerais heureux, en ce qui me concerne, si le Congrès voulait bien prendre en consideration le plan que j'ai eu l'honneur de lui soumettre, et prier l'ancienne Commission de la Carte d'Europe, dont les pouvoirs, lors de la dernière session, ont été étendus au globe tout entier, de choisir ce projet comme base de ses discussions.

Sujet No. 2: Différentiation Dans Les Magmas Ignés.

1. R. A. Daly, *Sills and laccoliths illustrating petrogenesis* (page 189).
2. Alfred Harker, *Fractional crystallization the prime factor in the differentiation of rock magmas* (page 205).
3. J. P. Iddings, *Some examples of magmatic differentiation and their bearing on the problem of petrographical provinces* (page 209).
4. H. S. Washington, *The volcanic cycles in Sardinia* (page 229).
5. W. H. Hobbs, *Variations in composition of pelitic sediments in relation to magmatic differentiation* (page 241).
6. Discussion.

SILLS AND LACCOLITHS ILLUSTRATING PETROGENESIS.

BY

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Geology has shown that erosion has very seldom, if ever, penetrated the earth's crust to depths measurable in tens of kilometres. In very few regions can it be even suspected that erosion has penetrated as much as ten kilometres. Obviously the field worker is compelled to deduce only indirectly the character of the lower and greater part of each of the world's batholiths, stocks, and independent dikes. These "bottomless" igneous masses represent the chambers where igneous magmas have been developed or into which they have been erupted from the earth's invisible interior. A final theory of igneous rocks must be founded on reasoning as to the magmatic events in batholith and primary dike at depths never exposed by denudation. For example, the key to the origin of the peerless body of rhyolite in Yellowstone National Park is to be found, not in the study of it merely as a volcanic mass, but in the study of such bodies as the neighbouring, somewhat older, Boulder batholith. Geologically and chemically this batholith has features which should, in essentials, characterize the mass crystallized below and in continuity with the rhyolite. From the Montana area BARRELL, WEED, KNOPF, and others have already furnished field data which, interpreted in the light of experience in other batholithic regions, suggest the origin of the great granite-quartz monzonite body.

With unexampled skill and thoroughness BARRELL has described the contact relations of its Marysville satellite, a typical stock which has been emplaced by the same mechanism as that of the Boulder batholith itself. BARRELL demonstrated the replacement of the invaded formations and, like USSING, was an independent author of the stoping hypothesis. This method of irruption necessarily implies deep-seated assimilation by the invading magma.

An attentive study of batholiths and stocks has thus led, through indirect yet cogent reasoning, to belief in large-scale assimilation at subsurface levels which, for the most part, have never been exposed by erosion. The syntectic magmas so formed have been differentiated, also at deep levels in each chamber. Full belief in magmatic assimilation on a batholithic scale is only possible after a clear idea is gained as to the actual process of this differentiation in depth. In the nature of the case such a conception cannot be perfected by the most prolonged study of stock or batholith alone.

The writer believes that there is a way out of this difficulty—by laying appropriate stress on the facts already made known regarding magmatic processes in concordant injections, laccoliths and intrusive sheets. Many of these are of great enough size to permit of differentiation in spite of the chilling effect of roof and floor rock. A smaller number are sufficiently large to have incorporated some country rock before the final magmatic splitting. According to conditions, denudation has laid bare contacts at either roof or floor or at both. Exposure of the last mentioned type is ideal; but in some cases the injections furnish valuable facts even where the floor contact alone is visible, the roof rock having been stripped away completely. The following table summarizes the information already derived from concordant injections of all three types of exposure. These bodies and their like are of unrivalled importance in petrogenic theory.

At least seventy different bodies are recorded in the table. In twenty-nine of these sills and laccoliths, gravitative differentiation is clearly shown and it has probably characterized six others at least. In most cases the available evidence suggests that the units assembled by gravity were liquid fractions, non-consolute at the moment of differentiation. The splitting is suggestively analogous to that seen in the stratified arrangement of colloids in water which has stood undisturbed for some months.[1]

Gravitative control over the differentiation is indirectly illustrated in the upward transfer of some of these fractions, including aplitic and [illegible]litic magmas, which have risen in the chamber with the aid of magmatic gases. But even thick laccoliths of the Henry Mountain type—highly viscous and relatively cool at the time of injection—can not be expected to show pronounced gravitative splitting in place.

At least sixty species of igneous rocks, besides transitional and hybrid types, are represented in the list. All of the plutonic families quantitatively important in the world—granite, granodiorite, diorite, gabbro, anorthosite, syenite, foyaite, peridotite—are represented; and, in addition, many of the rarer families—analcitic and leucitic types, essexite, theralite, teschenite, urtite, ijolite, jacupirangite, lujavrite, shonkinite, borolanite, magnetite ore, chromite ore, sulphide ore, etc. This great range of magmatic types is a principal indication of the value of these injections for petrogenic theory.

Some of the bodies illustrate a principle which seems certain of increasing emphasis, namely, the influence of contact chilling in inhibiting differentiation. The contact phase, a more or less continuous shell, thus represents the original magma. The other phases, enclosed by this shell, are the products of its splitting. The development of chilled phases in differentiated sheets has been described by LEWIS (Palisades of New Jersey), by G. W. TYRRELL (Lugar, Benbeoch, and Howford Bridge sills of Scotland), by JEVONS and others (Prospect intrusion of New South Wales), and by the present writer (Moyie and other sills of the Purcell mountains, British Columbia). The writer has also suggested a similar explanation for the

[1] Cf. R. S. SYMMONDS, "*Our Artesian Waters*," Sydney, N.S.W., 1912, pp. 42-50.

TABLE OF NOTABLE CONCORDANT INJECTIONS.

Locality	Character of Body	Length Km.	Maximum Thickness M.	Significant Country Rocks	Character of Differentiation	Rock Species Differentiated
1. Sudbury, Ontario.	Interformational sheet	65	3,000±	Huronian sandstone and conglomerate; pre-Huronian gneiss and schists.	Grav.	(a) Micropegmatitic granite and granodiorite, quartz diorite. (b) Abnormal intermediate types. (c) Norite. (d) Sulphide ores.
2. Gowganda Lake, Ontario.	4 sills.	?	15–150	Huronian argillite, quartzite, and conglomerate: pre-Huronian schists and granite.	Locally grav.	(a) Micropegmatite and soda aplite. (b) Diabase and gabbro with soda aplite veins (Syenite as differentiate in Lost Lake sill cutting slate).
3. Cobalt Lake district, Ontario.	Sills.	20+	150+	Ditto.		Diabase and micropegmatitic diabase, with spots, dikes, and irregular masses of soda aplite.
4. Pigeon Point, Minnesota.	Sheet (dike?).	+	200+	Animikie argillite, sandstone.	Probably grav.	(a) Micropegmatitic granite ("quartz keratophyre"). (b) Abnormal intermediate types. (c) Olivine diabase.
5 Duluth. Minnesota.	Laccolith	200	6,000+	Animikie argillite, sandstone; pre-Animikie gneiss, schists, etc.	Grav.	(a) Micropegmatite, granite, syenite. (b) Anorthosite, gabbro, norite. (c) Femic norite, pyroxenite, dunite, magnetite ore.
6. Bad River, Minnesota.	Laccolith (part of the Duluth laccolith?).	80+	2,500+	Ditto	Grav.	Granite (??) Gabbro.

TABLE OF NOTABLE CONCORDANT INJECTIONS—*Continued.*

Locality	Character of Body	Length Km.	Maximum Thickness M.	Significant Country Rocks	Character of Differentiation	Rock Species Differentiated
7. Moyie River, British Columbia.	Four or more sills.	9+	10-320+	Beltian (latest Pre-Cambrian) quartzite and silicious argillite.	Grav.	(a) Abnormal, micropegmatitic granite. (b) Abnormal intermediate types. (c) Hornblende gabbro
8. Cranbrook district, B.C.	Several sills	?	?	Ditto	Grav.	Ditto, with local phases of normal diallage gabbro.
9. Near Bonner's Ferry, Idaho.	Sill (with similar sill).	?	240	Beltian argillite, sandstone.	Grav.	(a) Granodioritic type. (b) "Diorite" (hornblende gabbro?).
10. Flathead River, Montana.	Sill.	?	?	Ditto	Grav.	(a) Micropegmatitic granite. (b) "Diorite" (hornblende gabbro?).
11. Wishards Peak, Idaho.	Sill.	33+	?	Ditto		Diabase, gabbro, "basaltic" phase, interstitial micropegmatite
12. Palisades, New Jersey	Sheet.	160	300+	Triassic sandstone, shale.	Grav.	(a) Diabase with micropegmatitic phase. (b) Olivine diabase.
13. Preston, Connecticut.	Laccolith.	10	1,000+	Undated quartz schist, hornblende schist.	Grav.	(a) Oligoclase granite. (b) Quartz-hornblende gabbro. (c) Gabbro.
14. Near Lake Wettern, Sweden.	Sills ("beds").	?	?	Almesåkra shale, sandstone.	?	Diabase and micrographic quartz diabase.
15. Ångermanland, Sweden.	Sills.	?	?	Pre-Cambrian sandstone, granite.	?	Olivine diabase and micrographic quartz diabase.

Locality	Character of Body	Length Km.	Maximum Thickness M.	Significant Country Rocks	Character of Differentiation	Rock Species Differentiated
16. Kilsyth-Croy district, Scotland.	"Laccolith."	5+	100+	Carboniferous sandstone, limestone, etc.	Gaseous transfer	Basaltic diabase, micropegmatitic quartz diabase, soda aplite, and micropegmatite veins.
17. British Guiana.	Sills and laccoliths.	?	?	Thick sandstone and conglomerate (undated).	?	Diabase, augite granophyre (micropegmatite).
18 Bushveldt, Transvaal.	Laccolith.	400	?	Pretoria sandstone, etc.; Black Reef.	Grav.	(a) Granite, generally micropegmatitic. (b) Norite, gabbro. (c) Pyroxenite, magnetite ore, chromite ore.
19. Insizwa Mt., East Griqualand.	Cross-cutting sheet.	30+	900	Karroo sandstone, shale.	Grav.	(a) Norite and gabbro with micropegmatitic segregations and veins of micropegmatite. (b) Olivine norite and olivine gabbro. (c) Peridotite and sulphide ores.
20. Pretoria district, Transvaal.	Sills.	?	?	Pretoria sandstone, shale.	?	Diabase or dolerite with micropegmatitic phases.
21. Natal.	Sill.	?	?	Undated sandstone.	?	"Basalt" and micropegmatitic "hybrid rock."
22. Sinni valley, Italy.	Laccolith.	?	300+	Eocene argillite, limestone, etc.	Grav.	(a) Granite, aplite. (b) Plagioclasite. (c) Gabbro. (d) Serpentine (peridotite).

TABLE OF NOTABLE CONCORDANT INJECTIONS—*Continued.*

Locality	Character of Body	Length Km.	Maximum Thickness M.	Significant Country Rocks	Character of Differentiation	Rock Species Differentiated
23. Port Orford quadrangle, Oregon.	Laccoliths?	?	?	Cretaceous sandstone, shale; pre-Cretaceous argillite, phyllite, etc.	?	Gabbro with dacitic phases.
24. Shinumo, Arizona.	Sill.	?	280	Unkar sandstone, argillite, limestone.	Grav.	(*a*) Syenite. (*b*) Diabase.
25. Globe district, Arizona.	Sills and irregular masses.	?	?	Paleozoic shale, limestone, quartzite.	?	Syenite. Diabase.
26. Electric Peak, Yellowstone Park.	Sill.	?	9	Undated shale.	Grav.	(*a*) Feldspathic (shoshonitic phase). (*b*) Augitic (absarokitic phase).
27. Thunder Bay, Ontario.	Sills.	?	Up to 150	Animikie argillite.	?	Diabase, anorthosite.
28. Glamorgan township, Ontario.	Laccolith?	13	?	Pre-Cambrian amphibolite and limestone.	Grav.	(*a*) Gabbro with anorthositic phases. (*b*) Pyroxenite, hornblendite, iron ores.
29. Morin district, Quebec.	Laccolith.	80+	?	Pre-Cambrian gneiss, limestone, etc.	Grav.	Anorthosite with quartzose phases. Gabbro (subordinate).
30. Chibougamau district, Quebec.	Laccolith?	45+	?	Keewatin greenstones.	Probably grav.	(*a*) Anorthosite, gabbro. (*b*) Basic norite, pyroxenite, iron ores.
81. Bergen district, Norway.	Laccolith.	40	?	Pre-Cambrian gneiss, granite, and schists.	?	Anorthosite, with pyroxenite and titaniferous iron ores.
32. Island of Skye, Scotland.	Sills.	?	?	Tertiary basaltic lavas and agglomerates.		Anorthosite in banded gabbro.

Locality	Character of Body	Length Km	Maximum Thickness M.	Significant Country Rocks	Character of Differentiation	Rock Species Differentiated
33. Island of Rum, Scotland.	Sills.	?	?	Basic volcanics.		Allivalite, peridotite.
34. Natal and Zululand.	Sills.	?	?	Permian sediments.		Dolerite, anorthosite.
35. Shonkin Sag, Montana.	Laccolith.	5	45	Cretaceous and older shale, sandstone, and limestone.	Grav.	(b) Syenite. (c) Transition types. (d) Shonkinite. (a, e) Leucite-basalt porphyry (last a chilled phase at top and bottom).
36. Square Butte, Montana.	Laccolith.	5	350+	Ditto.		(a) Syenite. (b) Shonkinite.
37. Ice River, British Columbia.	Irregular laccolith.	5±	400+	Cambrian limestone, argillite, etc.	Grav.	(a) Sodalite syenite. (b) Foyaite, urtite, ijolite, jacupirangite, pyroxenite.
38. Lugar, Scotland.	Sill.	5.5	42	Carboniferous and older limestone, argillites, sandstone, etc.	Grav.	(b) Teschenite. (c) "Picrite." (a, d) Theralite (chilled phase above and below).
39. Inchcolm Island, Scotland.	Sill.	0.8+	20+	Shale and sandstone, (age?).		Teschenite, picrite.
40. Benbeoch, Ayrshire.	Sill.	?	?	?	Grav.	(a) Femic theralite (kylite). (b) "Kylite-picrite."
41. Castle Craigs, Ayrshire.	Sill.	?	?	Carboniferous shale, sandstone, limestone and marls.	Grav.	(a) Nephelite teschenite. (b) Hornblende teschenite. (c) "Picrite."

TABLE OF NOTABLE CONCORDANT INJECTIONS—*Continued.*

Locality	Character of Body	Length Km.	Maximum Thickness M.	Significant Country Rocks	Character of Differentiation	Rock Species Differentiated
42. Howford Bridge, Ayrshire.	Sill.	?	?	Permian lavas and Carboniferous limestone, shale, etc.	"Probably" grav.	(*a*) Analcite syenite. (*b*) "Essexite-dolerite."
43. Cnoc-na-Sroine (Loch Borolan) Scotland.	Laccolith.	6+	400+	Cambrian limestone, Moine schists, Lewisian gneiss.	Grav.	(*a*) Quartz syenite. (*b*) Quartz-free syenite. (*c*) Nephelite syenite, borolanite, ledmorite.
44. Lurcombe, Devon.	Sill.	?	42	Carboniferous shale, limestone, sandstone, Devonian limestone.	?	Augitic teschenite, camptonitic teschenite.
45. Ilimausak, Greenland.	Irregular laccolith? (composite).	15	?	Sandstone, granite.	Grav.	(*a*) Arfvedsonite granite. (*b*) Quartz syenite. (*c*) Pulaskite. (*aa*) Foyaite (chilled phase?). (*bb*) Sodalite foyaite. (*cc*) Naujaite. (*dd*) Lujavrite and kakortokites.
46. Kola peninsula, Lappland.	Laccolith.			Paleozoic sediments; gneiss.	Grav. in part.	(*a*) Lujavrite, urtite, etc. (*b*) Chibinite, etc.
47. Prospect Mt., New South Wales.	Laccolithic sheet.	2 5	100+	Triassic shale, Permo-Carboniferous sediments.	Grav.	(*a*) Essexite with soda-aplite veins and segregations. (*b*) Femic essexite.

Note.—In the last column the letters in italics show the order of superposition of the rocks in the gravitatively differentiated injections.

leucite basalt porphyry enclosing the syenite and shonkinite of the Shonkin Sag laccolith.[1] Another example is perhaps to be found in the Electric Peak sill listed in the table.

As a rule the chilled phase at the roof merges into the salic phase of gravitative differentiation. This relation has often been incorrectly described as "contact basification." The difficulties inherent in the application of Soret's principle or of the principle of fractional crystallization are seen to have given needless trouble in petrology.

In general, the larger the body the more advanced is gravitative splitting The huge Bushveldt, Duluth, Sudbury, Ilimausak, Chibougamau, and Morin bodies have been respectively split into salic and highly femic submagmas, developed on the great scale. The thinner Purcell, New Jersey, Natal Scottish, and Australian injections are less thoroughly differentiated. This rule suggests the reason for the salic and homogeneous nature of normal batholithic rocks.

On the other hand, some of the thinner sheets are more or less drastically differentiated. Those at Shonkin Sag, Square Butte, Ice River, Lugar, and Cnoc-na-Sroine (Loch Borolan) show that alkaline *magmas* must have relatively low viscosity in spite of rapid chilling and in face of experimental proofs that many artificial alkaline *melts* are highly viscous. The contrast suggests that these natural magmas have been specially charged with volatile fluxes—a conception supported by the mineralogy of alkaline rocks and one clearly implied in the hypothesis that these magmas are derivatives of sedimentary syntectics.

The published descriptions of most of the igneous bodies listed in the table illustrate the "freezing-in" or "fixing" of small masses of one differentiate in the crystallized equivalent of its complementary magma. Thus, the micropegmatitic roof differentiate in a Purcell, Sudbury, Minnesota, or South African sheet always overlies a gabbroid or diabasic phase carrying interstitial micropegmatite, or schliers or "veins" of the same material. These have evidently been trapped during the solidification of their respective hosts. A large-scale parallel is found in the "transition" or "intermediate" rocks in differentiated injections. Sills and laccoliths evidently throw light on the origin of many plutonic, hypabyssal, and volcanic species which are found only in small volumes.

The anorthosites of the world are best regarded as differentiates of gabbroid (basaltic or diabasic) magmas. The positions of the anorthosite masses in the Duluth laccolith and the Thunder Bay sills suggest some degree of gravitative control over the splitting. The described field relations of the large Bergen, Morin, Glamorgan, and Chibougamau bodies strongly indicate their laccolithic nature. In each of them the anorthosite is specially developed at or near the roof, while pyroxenites, hornblendites, peridotites, or iron ores are found at or near the floor. The writer has come, in fact, to suspect that all anorthosite occurs in injected bodies of the sill, laccolith,

[1] R. A. DALY, Memoir No. 38, Geol. Survey of Canada, 1912, p. 251.

chonolith, or dike type; and that even the enormous masses found in Quebec, Labrador, New York State, Norway, etc., are similarly not to be regarded as "bottomless" batholiths. Combining the facts known about anorthosites, and especially considering the bodies listed in the foregoing table, the most promising hypothesis remains that the larger masses are gravitative differentiates of gabbroid (basaltic) magma. The relatively minute masses found in the banded gabbros of Skye and other regions, and as schliers in many small bodies of gabbro, are clearly local differentiates "frozen in" before gravity could assemble them in thicker sheets. Sills and laccoliths of pure anorthosite show that the splitting has often taken place in depth, before injection at visible levels.

Because of their limited supply of heat most sills and laccoliths have not assimilated important amounts of their country rocks. Yet the flat shape and great horizontal extension characterizing each of these intrusives types (all originally of basaltic composition) prove low magmatic viscosity, which means some degree of superheat. Large superheated injections must dissolve the invaded rocks to some extent. There is a tendency toward the formation of a chilled phase in the magma, whereby the country rock is protected against assimilation, but this tendency may be checked by the stirring of the magma during injection, by magmatic stoping, by "two-phase convection,"[1] and at the roof by the rise of volatile fluxes. All of these conditions are likely to affect such enormous bodies as the Sudbury sheet, the Bushveldt laccolith, and the Duluth laccolith. The chemical character of the invaded formations is obviously important; if they are calcareous or notably hydrous, the fluxing of the original magma at contacts is facilitated. The available field data show that the feeders of sills or laccoliths are comparatively narrow. The passage of the original hot magma through these channels must take considerable time, and thus allowance should be made for possible assimilation during as well as after injection. In the writer's opinion, all of the non-basaltic (non-gabbroid) rocks in the bodies tabulated have originated in syntectics. Faith in this conclusion cannot be won from the study of concordant injections alone, but it is significant that a considerable number of these are described as having been active solvents of their country rocks. Such is the case for the following:

Sudbury sheet (A. P. Coleman).
Pigeon Point sheet (W. S. Bayley and A. C. Lawson).
Moyie and other Purcell sills (R. A. Daly).
Bonner's Ferry and Flathead River sills (F. C. Calkins).
Duluth laccolith (N. H. Winchell and others).
Insizwa sheet (A. L. du Toit).
Natal sills (W. Anderson; *see* G. T. Prior in bibliography).
Ångermanland sills (A. G. Högbom).
Kilsyth-Croy laccolith (G. W. Tyrrell).

[1] See Proc. Amer. Acad. Arts and Sciences, Vol. XLVII, 1911, p. 76.

Prospect intrusion (H. S. JEVONS and others).
Gowganda Lake sills (N. L. BOWEN).

The greatest laccolith on record—that in the Bushveldt—has, in its upper levels, a vast development of "red granite," which is a strict homologue of the "red rock" of the Duluth laccolith. The argument for a secondary origin of these salic differentiates is strong, as it so thoroughly accords with the proofs of secondary "red rock" or micropegmatite at Pigeon Point, Sudbury, and the Moyie river.

The analcitic phases of the sills at Teschen, which are partly diabase and partly teschenite, can be accounted for by the interaction of diabasic (basaltic) magma on the invaded basic, hydrous sediments. An analogous explanation is suggested for the analcitic rocks in the sills at Lugar, Inchcolm, Benbeoch, Castle Craigs, and Howford Bridge, and for the leucitic phase of the Shonkin Sag laccolith. Elsewhere, the writer has published the thesis that the foyaitic types of Ice River and Cnoc-na-Sroine (Loch Borolan), as well as the alkaline types at Square Butte, Shonkin Sag, etc., are differentiates of syntectics in which the invaded limestones have played an important role.[1] It may be noted that the induction on which that hypothesis was based has been greatly strengthened by a more recent, more complete survey of the world's alkaline-rock terranes. Similar statistics will soon be published which go far in favouring the idea of sedimentary control during the formation of syenitic and granodioritic magmas.

In general, the tabulated sills and laccoliths illustrate a principal deduction from the assimilation hypothesis: the silica content and related chemical features of the roof differentiate should vary with the chemical nature of the rock assimilated. The salic phase of a Moyie sill (cutting thick quartzites) is an abnormal granite; that of the Shinumo area (cutting shales, limestones, and sandstones) is a syenite; that of the Port Orford intrusives (cutting dominant argillite, with sandstone) is a dacite of granodioritic composition. Limestone control is suggested in the leucitic and nephelitic differentiates above noted. The special effects of resurgent water (that absorbed from sediments) has already been found in the analcitic differentiates and in the commonly developed soda aplites and albitic veins of many of these injections.

The principle of magmatic overhead stoping has been demonstrated in the Sudbury sheet (COLEMAN); in the Purcell sills (DALY); in the Pigeon Point intrusive (BAYLEY); in the Duluth laccolith (WINCHELL and others); and in the Ilimausak intrusion (USSING). LEWIS, TAYLOR, and JEVONS have given figures suggesting that the exceptional underhand stoping has taken place at the New Jersey Palisades and at Prospect mountain, New South Wales.

More than 75 per cent. of the injections listed contain gabbroid or diabasic (basaltic) phases. Of the remaining sixteen sills and laccoliths, several contain important phases which are most simply and probably explained as

[1] R. A. DALY, Bull. Geol. Soc. America, Vol XXI, 1910, p. 87.

modified basaltic magma. Such are: the leucite-basalt porphyry of Shonkin Sag; the "picrite," "essexite-dolerite," and teschenite of the Scottish and Austrian sills; the essexite of Prospect mountain; and the rocks of the Electric Peak sill. Basaltic magma has predominated in injections that show important assimilation. These facts agree with the conclusion that basaltic magma has been the heat-bringer and chief agent in petrogenesis during later Pre-Cambrian and all subsequent time. Needless to say, however, the justification for that wide-reaching idea is to be found only in an induction regarding igneous bodies of all classes.

The table illustrates again and again the "antagonism" between granitic and basaltic magmas, which has been so justly emphasized by LOEWINSON-LESSING;[1] under certain, often repeated conditions these magmas become non-consolute and gravitatively separate.

The Moyie sills and other sills of the Purcell mountains illustrate the principle of satellitic injection after gravitative differentiation. At several localities, thin sills of pure micropegmatitic granite overlie much thicker sills of dominantly gabbroid composition. The former are best interpreted as late offshoots from the larger bodies.[2] Similarly, numerous sills of pure anorthosite are apophysal from several of the large anorthosite injections. Dikes of salic differentiates in and from the injections listed in the table, are generally narrow but are quite common.

In some cases salic differentiates seem to have been actually erupted at the earth's surface. The acid lavas overlying the Duluth, Bushveldt, Natal, and Purcell bodies are probably of this origin.

It is worthy of note, however, that no effusive equivalent of anorthosite has yet been found. Herein we have another fact bearing on the origin of this remarkable rock. Possibly the fact may be correlated with the evidence of low magmatic temperature so often found in the protoclastic structure of anorthosite (ADAMS, KOLDERUP). The differentiation of the feldspathic magma is likely to take place only at a low temperature. It lacks the powerful aid of resurgent gases. For two reasons it would seem difficult for this monomineralic magma to escape at the earth's surface.

Lastly, sills and laccoliths illustrate the principle of the horizontal migration of magmas, both primary and secondary. Such bodies have been formed by the lateral spreading of magma from feeding channels for distances often to be measured in scores of kilometres. Widely spaced dikes were the feeders of the Whin sill, with its famous length of outcrop; of the sills of Fifeshire, Cape Colony, Natal and Zululand; and of the Palisades sheet, 160 kilometres in length. Such sills have horizontal extensions of the same orders of magnitude as those characterizing the Sudbury sheet and the Bergen, Bad River, Duluth, or Bushveldt laccolith. Though the feeders of these greater bodies are not easily identified, it seems likely that each body represents horizontal migration of magma for very long distances. Thus, a study of

[1] F. LOEWINSON-LESSING, Compte Rendu, Cong. géol. internat., VIIe session, 1897, p. 375.

[2] Memoir No. 38, Geol. Surv. of Canada, 1912, p. 250.

concordant injections leads to the conclusion that secondary magmas (syntectics or differentiates of syntectics) may be erupted at points far from their parent chambers. The principle has been long recognized but its quantitative importance has still to be appreciated. The facts determined for the greater sills and laccoliths cause one to suspect such horizontal migration of the magmas which have crystallized as the foyaities, naujaites, lujavrities, and phonolites of the Julianehaab (Greenland) and Cripple Creek (Colorado) districts. These rocks cut batholithic granites and there is no local indication of sedimentary control in the origination of each magma. Yet we know that alkaline magmas were largely generated in and below the thick limestones just west of Cripple Creek and the crest of the Colorado Front range. Moreover, we must believe that material has flowed laterally for a long distance when the great Front Range dome was uplifted. The geology of Greenland is too little known that the hypothesis can be applied to the foyaites described by Ussing. The calcareous Arsuk group of sediments may have taken part in their formation within one or more chambers distant from Kangerdluarsuk (Julianehaab). Yet the principle of horizontal migration is so clearly demonstrated that the few known exceptions like the two mentioned cannot invalidate the rule connecting most alkaline magmas with calcareous sediments. Other applications of the principle scarcely need emphasis on this occasion.

APPLICATION TO FLOORLESS INTRUSIVE BODIES.

The full bearing of these conclusions on the batholithic problem can only be discussed in terms of some speculation regarding the earth's interior. Combining the facts and deductions obtained from many leaders in geology and petrology the writer has developed an eclectic theory of the igneous rocks.[1]

A study of plutonic and volcanic sequences, together with induction regarding the distribution and relative quantities of eruptive rocks, has suggested to him the existence of a continuous basaltic *couche* or substratum below the visible rocks of the earth's crust. This substratum material has been locally eruptible since an early Pre-Cambrian period and it is the only primary magma which has been eruptible during that time. In the areas of the continental plateaus at least, this substratum is overlain by an acid shell (chemically of granitic composition) which was formed by a primitive liquation in the earth. This shell has been modified into the Pre-Cambrian acid gneisses. It is overlain by an interrupted sedimentary blanket, generally thin but locally thickened in geosynclines. The geosynclinal prisms are generally further thickened by orogenic crumpling.

All igneous action since the early Pre-Cambrian has been occasioned by the rise of the primary basalt into the overlying shell, which has been locally fissured. The resulting injections are vertical and dike-like in form, and thin out more or less completely in the superficial earth-shell of orogenic compression. These primary bodies may be called abyssal magmatic wedges.

If an abyssal wedge extends to the surface it may form basaltic fissure-

[1] Memoir No. 38, Geol. Survey of Canada, 1912, pp. 677-791.

eruptions or basaltic volcanoes of the central type. If the wedge is too narrow for significant assimilation of the wall-rocks, the basalt of the volcanic vent may, with increasing concentration of gas in the vent, differentiate gravitatively into pyroxene andesite and an ultra-femic phase. If resurgent water or wall-rock is dissolved, small amounts of other types (trachytes, phonolites, etc.) may be differentiated in the pipe.

The abyssal wedges are of maximum size after mountain-building has locally sheared the earth-shell of compression from the underlying shell of tension. These greater wedges must stope and assimilate their wall-rocks on a large scale, thus assuming the batholithic character. Because of their prolonged magmatic life, differentiation in batholithic chambers should be advanced. The visible rock of a batholith is generally granite because of the dominance of the acid earth-shell in the walls of the wedge. If argillites or other rocks of medium acidity are assimilated in large amount, the differentiate should reflect this influence. The field relations suggest that granodiorites, most quartz diorites, and syenites, with their hypabyssal and volcanic equivalents, are to be so explained. If the non-silicic limestone or dolomite is dissolved, the salic differentiate must differ from granite still more thoroughly. The comparatively rare stock and batholithic rocks bearing essential nephelite, leucite, sodalite, etc., seem to represent this case.

The writer believes that the floored injections discussed in this paper furnish many facts corroborating the eclectic theory thus briefly sketched. They illustrate:

(a) Proofs of superheat in basaltic magma.

(b) Dominance of basaltic magma in the earth's eruptivity, both in space and time.

(c) Assimilation by basaltic magma, generally in proportion to its volume.

(d) Magmatic stoping.

(e) Gravitative differentiation of basaltic magma.

(f) Gravitative differentiation of syntectics of basaltic magma with country rocks ranging in acidity from zero nearly to 100 per cent.

(g) Chemical variation of the salic differentiate with the chemical nature of the absorbed rocks.

(h) Pneumatolytic differentiation.

Among special points bearing on the batholithic problem the following may be summarized. Sills and laccoliths suggest or demonstrate:

(a) The "antagonism" between basalt and granite—a principle which seems to have controlled the primitive separation of the earth's acid (granitic) and basaltic shells.

(b) The great number of igneous species syngenetic with basaltic (gabbroid or diabasic) rock.

(c) The advance of magmatic differentiation roughly in proportion to the volume of the magma.

(d) The origin of many intermediate types (imperfect differentiation).

(e) The extraordinarily low viscosity of many intrusive alkaline magmas.

(f) The origin of most basic contact phases—here interpreted as due to chilling.

(g) The origin of anorthosite—a direct differentiate of basaltic magma under plutonic conditions. The splitting is performed in floored chambers of the laccolithic order, *not* in batholithic chambers, though some assimilation may take place in the body which finally shows an anorthositic phase.

(h) Transitions in the field from rocks of basaltic composition to teschenites, essexites, and other alkaline species.

(i) Satellitic injection—implying the magmatic origin of many hypabyssal and volcanic rocks in the great batholithic chambers (basaltic wedges).

(j) Horizontal migration of magmas—illustrating the fallacy of assuming that the character of visible country rocks is always a test of the assimilation theory.

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FRACTIONAL CRYSTALLIZATION THE PRIME FACTOR IN THE DIFFERENTIATION OF ROCK-MAGMAS.

BY

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The problem of magmatic differentiation is one which involves the application of physical and chemical principles to the elucidation of geological phenomena. I shall approach it from the geological side, while laying stress on those considerations which seem to conduct us most directly to a physico-chemical interpretation of the facts.

We may conveniently start from the generally received conception of a petrographical province, within which all the igneous rocks (belonging to one system of activity) are linked together by ties of consanguinity. Most geologists are agreed in attributing the general community of characters implied in this last term to actual derivation from a common stock, and in referring the wide variation which is compatible with such relationship to processes of differentiation which have operated upon the common stock-magma. I think we are forced to contemplate likewise an earlier differentiation of a larger order, by which the provincial stock-magma itself was derived from some more primitive stock. Not only do distinct provinces, with contrasted petrographical characteristics, sometimes coexist in neighbouring areas, but one and the same area my be invaded at different periods in its history by very different suites of igneous rocks. This forbids us to explain the existence of petrographical provinces by any permanent peculiarity inherent in different parts of the earth's crust.

Since every part of a given petrographical province must have been in communication, direct or indirect, with the common parent-magma, we may picture the latter as contained in an extensive intercrustal magma-basin underlying the area in question. It is not to be supposed that it remains as a great body of liquid magma throughout the whole time. Freezing and remelting may be admitted, and probably in the waning stages a division into a number of isolated smaller basins. Nevertheless, the history of igneous activity shows that the parent reservoir may be available as a source of extruded and intruded magmas at numerous epochs during a very long lapse of time, a duration sometimes commensurate with that of a whole geological period.

Now such a degree of permanence of a magma-basin as is thus implied clearly postulates approximate thermal and chemical equilibrium between the contents of the basin and the contiguous solid crust. Water and ice cannot continue to exist in contact with one another unless both are at the same temperature, the freezing-point of water. A liquid rock-magma differs from water in having, not a precise freezing-point, but a certain freezing-interval or temperature-range of crystallization. For any approach to permanent existence of a basin, we must suppose the temperature to be within this range, and probably in general in the lower part of the range. At a temperature in the upper part of the range of crystallization there would be a liquid magma enclosing scattered crystals; but at lower temperatures we must picture, rather, an open fabric or sponge of crystalline matter with interstices occupied by liquid magma. A mass of this composite nature will have some peculiar physical properties, unlike those either of a crystalline body or of a liquid.

It is scarcely necessary to enforce the intimate connection of igneous action with stresses in the crust of the earth. This is illustrated throughout the whole geological record by the relationship which is observed between igneous activity on the one hand and crustal displacements, such as folding and faulting, on the other. Consider then the effect of powerful mechanical forces applied to an extensive intercrustal reservoir, partly crystalline and partly liquid. If the crystals already build a continuous fabric, or become forced into contact with one another, they may be supposed to bear the brunt of the additional stress, to the relief of the interstitial magma. In so far as this condition is realized, we have a case of the "unequal pressure" recently discussed by JOHNSTON and ADAMS[1]. Instead of a rise of melting-points under increased pressure, there will be a lowering of melting-points with temporary local fusion. It would be of interest to pursue this consideration, but we are concerned more particularly with crustal stresses as a factor in differentiation. The point to be remarked is that a composite mass, partly crystalline and partly liquid as supposed, is, when subjected to non-uniform pressures, *essentially unstable* in respect of composition. The crystalline skeleton will yield to deformation, and the interstitial liquid will be forced from places of greater pressure to places of less pressure. Finally it may be more or less completely driven out, as water is squeezed out of a sponge.

Here, then, we have differentiation as a necessary consequence of fractional crystallization in conjunction with crustal stresses. The crystalline and liquid parts, which come to be mingled in changed proportions, or may be almost completely separated, necessarily differ in composition. The kind and degree of difference will depend on the "order of crystallization" in the original magma and on the extent to which crystallization (or fusion) had proceeded prior to the separation; that is, in other words, on the temperature at which the separation was effected. In intruded magmas a separation of this kind cannot proceed very far, unless the country rocks have previously been raised to a high temperature: the case is illustrated by the extruded pegmatites of some regions. In intercrustal basins a like action on a large scale would seem to be a normal and necessary incident. I think we may

[1] Amer. Journ. Sci. (4) Vol. XXXV, 1913, pp. 205-253.

recognize in it the chief cause of that primary differentiation, in a horizontal ..., by which petrographical provinces come into existence. It is a striking fact that contrasted provinces are often divided by important orographic lines, and in other ways the distribution of different kinds of igneous rocks often shows a remarkable relation to crust-movements.

The evolution of a varied suite of igneous rocks from the common stock-magma of a petrographical province represents, no doubt, the result of repeated processes of differentiation. It is probable that fractional crystallization has been an essential factor at more than one stage, and that the mechanical element may still be important, if no longer dominant. Adopt for a moment the chemist's point of view. In their chemical aspect rock-magmas are merely solutions, with properties not different in kind (though they may differ in degree) from those of other solutions more easily handled in the laboratory. Magmatic differentiation is another name for fractionation. Now there are various fractionating processes by which a uniform solution can be separated into portions differing in concentration; but, setting aside volatile phases, it will be found that the chemist, practically confronted with this problem, can do little without proceeding to actual crystallization.

It is true that, according to the theoretical principles of equilibrium, a solution must vary from top to bottom in consequence of gravity; and it is also true that, if different parts of a solution be maintained at different temperatures, the concentration will vary accordingly. It may be urged that these effects, though negligible in a test-tube, will become important in a large body of fluid rock-magma. So much, I think, may be allowed, without admitting these factors to the same rank of importance as fractional crystallization. It is certain, at least, that both gravity and temperature-differences must acquire enormously increased efficiency as soon as crystallization has begun. The sinking of crystals as they form will produce much more decided effects than stratification of a still liquid solution under gravity, even when we allow for the possible case of imperfect mutual solubility; and continued crystallization in the coolest part of the solution will be a much more potent cause of variation than what is known as Soret's action.

The stratified magma-basin, with different magmas at different levels, one graduating into another, is a conception common to many geological speculations. It is supported by the frequent intimate association of very different igneous rocks, including such special features as heterogeneous intrusions, primary gneissic banding, hybrid rocks, composite dykes and sills, and the systematic distribution of cognate xenoliths and xenocrysts. It is necessary therefore to inquire how this conception harmonizes with what I have already said on the subject of intercrustal magma-basins.

Suppose such stratification brought about either by gravity acting upon a wholly fluid magma or (more effectively) by the sinking of crystals in a amgma still mainly fluid. In the former case the denser constituents, and in the latter case the earlier-crystallized minerals, will become concentrated in the lower layers. Broadly speaking, in most magmas, the denser constituents are also those which crystallize early. They are the more "basic" constituents in a generalized sense, according to ROSENBUSCH's "law of decreasing basicity." In general then the contents of a stratified magma-basin will become more basic downward and more acid upward. In so far as SORET's principle is operative, it tends on the other hand to a concentration of the earlier-crystallizing constituents in the upper and cooler layers; but this can be at most a trifling set-off against the more important effect.

The free fluidity here assumed implies a degree of super-heating which can only be temporary; but the resulting stratified arrangement, once established, will be a very important factor making for that relative permanence which seems to be demanded in our conception of a great magma-basin. Suppose cooling to proceed until the temperature at every level is in the lower part of the range of crystallization of the magma at that level. Then, since a more basic magma crystallizes at higher temperatures than a more acid one, there will be a steady increase of temperature from top to bottom of the basin. This condition will be promoted by the concentration of volatile fluxes in the upper part of the basin. The criterion of approximate thermal equilibrium between the magma-basin and the contiguous solid crust can now be applied to *each layer* of the stratified basin. The ideal case will be that in which the temperature-gradient within the basin approaches what we may term the normal rate for that region of the earth's crust. If we adopt CHAMBERLIN's planetesimal hypothesis, we are at liberty to suppose that, for depths at which magma-basins can exist, the normal temperature of the crust is nowhere much below that of incipient fusion.

In an already stratified disposition of partial magmas in the common reservoir we may most probably seek the explanation of the order of succession, that of decreasing basicity, which is so general a rule in a series of plutonic intrusions. In many cases such a plutonic series has been preceded by volcanic outbreaks, to which no simple rule of succession applies, and we may conjecturally place this volcanic phase anterior to the stratification of the magma-basin. On the other hand, there is almost always a final phase of minor intrusions, which figure as satellites of the several plutonic rocks, and must be supposed to have been derived from the partial magmas already separated. The effects of further subsidiary differentiation, which may be seen in the plutonic series itself, become more important among the minor intrusions, and especially among those which come latest in the succession. Very characteristic at this stage is a partition into complementary leucocratic and melanocratic derivatives, which differ very widely from one another. For this it is difficult to suggest any explanation other than fractional crystallization followed by mechanical separation—the squeezing of the sponge.

In the comparatively simple case of differentiation in place in a single body of intrusive rock we see the result of fractional crystallization not complicated by the mechanical factor. There is simply a concentration of the earlier-crystallized minerals towards the cooling boundary. The viscosity of the magma was in general too great, and the time too short, to allow any sensible stratification due to gravity; though evidence of this is found in some cases where the magma was exceptionally rich in water, as in some analcime-bearing rocks.

SOME EXAMPLES OF MAGMATIC DIFFERENTIATION AND THEIR BEARING ON THE PROBLEM OF PETROGRAPHICAL PROVINCES.

BY

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The igneous rocks of the region of the Yellowstone National Park have been described with more or less detail in publications of the United States Geological Survey, and elsewhere.[1] Those of Electric peak and Sepulchre mountain have been shown to be intrusive and extrusive members of what was probably one series of lavas erupted at one centre of volcanic activity in early Tertiary times. The chemical resemblances between the intrusive phanerites and porphyries of Electric peak and the extrusive flows and breccias of Sepulchre mountain have been discussed, and it has been pointed out that all of these rocks, together with those forming laccoliths, sills and dikes in the neighbouring portions of the Gallatin mountains, are probably genetically related, and are to be considered as differentiates of some common magma.

In like manner the intrusive rocks of the Crandall volcano, in the north-eastern corner of Yellowstone National Park Forest Reserve, and the extrusive lavas of this volcano and of the Absaroka range in which it occurs, have been shown to be chemically similar and presumably genetically related, that is, comagmatic. Moreover, the occurrence in this region of lava flows and dikes genetically related to the commoner lavas of the region, but differing from them to some extent in composition, has also been described, and these varieties have been named banakites, shoshonites and absarokites.

It is not necessary, therefore, to repeat any of the petrographical descriptions of these rocks, but it may be noted that, according to the custom of the Qualitative System of Classification, they have been named andesites of various kinds, dacites, rhyolites and basalts; also diorites, quartz-diorites, gabbros and granites, besides various kinds of related porphyries. It has been noted also that there are all gradations between what may be called different kinds of rocks in the region, but which are in fact only varieties or members of a continuous series of rock varieties. Some mineralogical differ-

[1] Iddings, J. P., Seventh Annual Report, U. S. Geological Survey, 1888, pp. 249-295; Twelfth Annual Report, U. S. Geol. Survey, 1891, pp. 569-664; with A. Hague and others, Monograph XXXII, pt. 2, U. S. Geol. Surv., 1899; Bulletin Phil. Soc. Washington, Vol. XI, 1890, pp. 191-220; Journal of Geology, Vol. III, 1895, pp. 935-959; Quarterly Journal Geological Society, London, Vol. LII, 1896, pp. 606-617; also *Igneous Rocks*, Vol. II, 1913, p. 463.

ences were noted between the phanerites in the conduit of the Crandall volcano and those in the conduit at Electric peak, the former ranging somewhat lower in silica and containing higher percentages of orthoclase. No special mineralogical differences were noted between the andesitic lavas of the Absaroka range and those of the Gallatin range, and analogous varieties

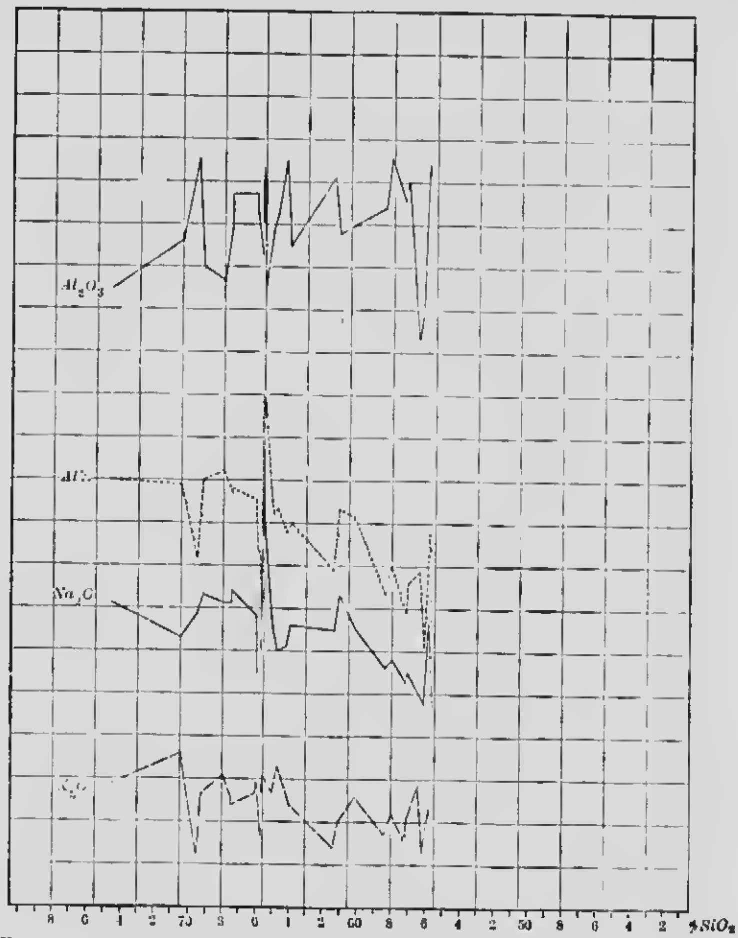

FIG. 1.—Molecular proportions of alkalies and alumina in igneous rocks of the Gallatin range, Yellowstone National Park.

in each series were named alike. When studied quantitatively, however, slight but systematic differences in composition are found to characterize the rocks of the two districts, or so much of them as have been investigated.

The only quantitative determinations of composition possible for such aphanitic and glassy rocks are those obtained from chemical analysis, and because of the variability of composition among rocks of any congenetic series it is necessary to analyze many varieties within each series in order to discover serial characteristics and avoid misleading generalizations that might be based on individual peculiarites. These more specific peculiarities

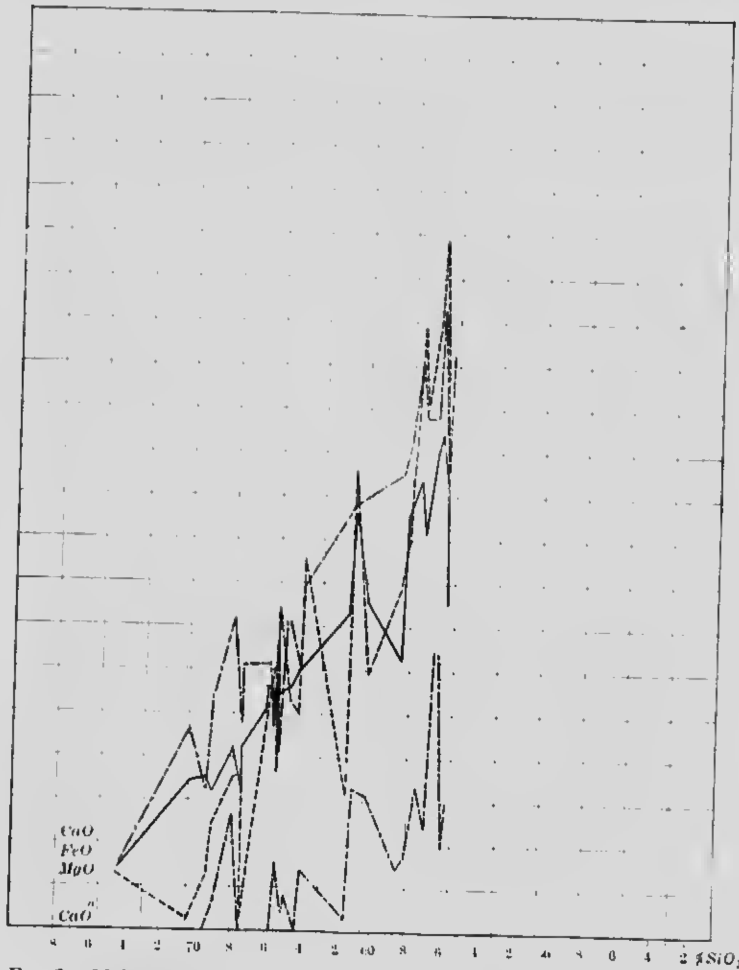

FIG. 2.—Molecular proportions of magnesia, lime and iron oxide in igneous rocks of the Gallatin range, Yellowstone National Park.

have their proper significance when they are considered in their proportionate relations to the dominant characteristics of the whole series.

Some of the chemical characteristics of the rocks of the Gallatin range appear when the chemical constituents in the rocks analyzed are plotted in diagrams in the manner already employed in earlier discussions of these rocks. In Fig. 1 are plotted the molecular proportions of potash, soda and alumina in 29 analyses of intrusive and extrusive rocks in this district, including the rocks of Electric peak and Sepulchre mountain. The abscissas in the diagram are percentages of silica in each analysis. The analyses of these rocks and all others referred to in this paper may be found in Bulletin 419 of the U. S. Geological Survey. A list of the names and silica percentages of the rocks from the Gallatin mountains is as follows:

74.51% SiO_2,	dacite-porphyry.	64.27% SiO_2,	hornblende-mica-andesite.
70.52 "	mica-dacite-porphyry.	64.07 "	quartz-pyroxene-mica-diorite.
69.54 "	dacite-porphyry.	61.50 "	hornblende-mica-porphyry.
69.24 "	quartz-mica-diorite-porphyry.	61.28 "	pyroxene-mica-diorite.
67.95 "	andesite, from breccia.	60.30 "	hornblende-pyroxene-andesite.
67.49 "	dacite.	58.44 "	hornblende-porphyry.
67.54 "	quartz-mica-diorite.	58.05 "	pyroxene-mica-diorite.
66.05 "	quartz-mica-diorite.	57.38 "	pyroxene-porphyry.
65.97 "	quartz-mica-diorite-porphyry.	57.17 "	pyroxene-andesite.
65.66 "	dacite.	56.61 "	hornblende-pyroxene-andesite.
65.64 "	hornblende-mica-andesite-porphyry.	56.28 "	pyroxene-mica-diorite.
65.63 "	hornblende-mica-andesite-porphyry.	55.92 "	hornblende-andesite.
65.60 "	quartz-mica-diorite.	55.83 "	pyroxene-andesite.
65.50 "	hornblende-mica-andesite.		
65.11 "	quartz-mica-diorite.		
64.85 "	quartz-mica-diorite.		

The most siliceous rock is from the marginal portion of the Holmes bysmalith, the least siliceous is andesitic lava of Sepulchre mountain. The rock series is characterized by relatively low and persistent potash, two or three times as much soda, and by quite persistent alumina. The total amount of alkalies is indicated by the dotted line in the diagram. The space between this line and the alumina line indicates in a general manner the amount of lime that enters anorthite molecules, except in rocks that have an excess of alumina molecules over those of lime, soda and potash. The irregular variations in these constituents correspond to variations in the differentiation of the magma with respect to compounds of soda, potash and lime, and also to ferro-magnesian compounds. Whatever the exact composition of the parent magma may have been from which the rocks of the Gallatin series differentiated, it was probably characterized by relatively low potash and about two and a half times as much soda, with about as much salic lime; that is, the molecules of alkalic feldspars, albite and orthoclase, were twice as numerous as those of lime-feldspar, anorthite.

In Fig. 2 the magnesia, iron oxide and lime in the analyzed rocks of the Gallatin range are plotted in the same manner as the alkalies and alumina are in Fig. 1. The ferric iron is reduced to ferrous and added to that determined as ferrous in the analyses. The total lime is shewn by the upper dotted line. From it has been deducted the lime calculated as entering normative anorthite, and the residue, or femic lime, is indicated by the lower dotted line. The differentiation of the magma with respect to these constituents is more pronounced than for the alumina and alkalies. They diminish regularly with increase of silica and increase notably with decrease of silica. The most variable constituent molecularly is magnesia. Lime is higher than iron oxide and magnesia in most of these rocks, and is nearly as high as the maxima of magnesia in five noticeable instances. The excess of the total lime over the total iron is pronounced. However, the femic lime is much less than the magnesia, is wanting in most of the more siliceous rocks, and is very low in most of the rocks with more than 62 per cent. of silica. It increases at about the same rate as the magnesia and total iron, but the maxima and minima of the two are not coincident; they vary independently of each other to a considerable extent. A large part of the lime in each rock is salic, that is, it enters feldspar molecules.

Variations in potash, soda and alumina in the intrusive and extrusive rocks of the Absaroka range, including those of Crandall volcano and the rhyolites of the plateau between the Absaroka and Gallatin ranges are shown in Fig. 3. Most of the rocks from the Absaroka range that have been analyzed were erupted in early Tertiary times, probably the Eocene, and are nearly contemporaneous with those of the Gallatin range. The rhyolites were erupted in late Tertiary time. The range of silica is somewhat greater than in the series from the Gallatin range, the rhyolites reaching 77.65 per cent. and the basalts 47.17 per cent., but the upper limit of the rocks from Crandall volcano is 71.60 per cent., in a granitic aplite. The basalts are associated with the gabbro of the Crandall volcano, and are early Tertiary. The list of the rocks analyzed is as follows:

77.65% SiO_2, rhyolite.
75.89 " rhyolite.
75.50 " lithoidite.
75.34 " rhyolite.
75.19 " rhyolite.
74.70 " obsidian.
72.59 " obsidian.
71.85 " rhyolite.
71.60 " aplite.
70.92 " rhyolite.
70.24 " mica-dacite-porphyry.
66.64 " syenite-porphyry.
64.61 " hornblende-mica-andesite.
64.40% SiO_2, augite-syenite-porphyry.
64.40 " quartz-mica-diorite-porphyry.
64.23 " granite-porphyry.
63.97 " quartz-mica-diorite.
63.76 " diorite.
63.42 " quartz-diorite-porphyry.
63.07 " quartz-syenite.
61.56 " hornblende-andesite.
61.45 " pyroxene-andesite.
61.16 " hornblende-mica-andesite-porphyry.

60.15%	SiO_2	hornblende-augite-andesite.
60.00	"	diorite-porphyry.
57.64	"	augite-andesite-porphyry.
57.26	"	dioritic facies of gabbro.
57.32	"	monzonite.
56.47	"	pyroxene-andesite.
56.21	"	orthoclase-gabbro-diorite.
55.93	"	orthoclase-gabbro-diorite.
53.89	"	basalt glass.
53.75	"	basalt.
53.56%	SiO_2	mica-gabbro-porphyry.
53.57	"	gabbro.
52.47	"	trachyte-andesite.
52.37	"	basalt.
52.18	"	diabase.
52.09	"	basalt.
51.81	"	gabbro-porphyry.
51.70	"	basalt.
51.70	"	basalt.
50.99	"	camptonite (?).
50.72	"	hornblende-pyroxene-andesite.
47.17	"	basalt.

Comparing Figs. 3 and 1, it is seen that the Absaroka series of rocks is richer in potash than the Gallatin series, while soda is nearly the same in both series. The total alkalies are distinctly higher in the Absaroka series. The alumina is about the same in both, within the range of the shorter series, but a noticeable decrease occurs in the rocks with more than 70 per cent. of silica. Pronounced variations in alumina and alkalies among rocks with nearly the same silica corresponds to differentiations with respect to feldspathic and ferro-magnesian, or mafic, compounds. Fig. 3 shows that the rocks of the Absaroka range, though so much like those of the Gallatin as to receive the same names, are quantitatively different from them in having relatively more orthoclase molecules and somewhat less anorthite molecules.

Fig. 4 shows the corresponding variations in lime, magnesia and iron oxide, and also in femic lime. In rocks with from 54 to 64 per cent. of silica these constituents are slightly lower than in corresponding rocks in the Gallatin series. The lime and magnesia are much alike in the Absaroka rocks, the magnesia being more variable, and being noticeably lower than the lime in the more siliceous rocks. The femic lime is highly variable and is similar to that in the Gallatin series. The highly differentiated condition of the rocks with from 50 to 54 per cent. of silica, and of those with from 62 to 65 per cent. is noticeable, and corresponds to reciprocal variations in alumina and alkalies.

From the foregoing diagrams have been omitted those exceptional rocks that have been called banakites, shoshonites and absarokites, and several other allied rocks. They are associated with the early Tertiary lavas and with some that are probably middle Tertiary. They are in part lava flows, in part dikes, and in two instances they are sills in the Gallatin mountains, and in one instance a flow near the base of the breccias of Sepulchre mountain. The variations in their constituents are shown in Figs. 5 and 6, and the list of analyzed rocks is as follows:

69.45%	SiO_2	glassy trachyte, Sunset peak.
60.89	"	quartz-banakite.
57.73	"	biotite-trachyte, Dike mountain.
57.29	"	quartz-banakite.
56.05	"	shoshonite.
54.97	"	shoshonite.
54.86	"	olivine-free shoshonite.
53.71	"	mica-gabbro.
53.49	"	shoshonite.
5[illegible].93	"	leucite-banakite.
5[illegible].86	"	shoshonite.
52.63	"	banakite.
52.49	"	leucite (?)-shoshonite.
52.33	"	banakite.
52.11	"	basalt.
52.10	"	augite-andesite-porphyry, upper portion of differentiated sill in Electric peak.
51.82%	SiO_2.	banakite.
51.75	"	shoshonite.
51.76	"	absarokite.
51.68	"	absarokite.
51.56	"	leucite-absarokite.
51.46	"	banakite.
51.17	"	augite-andesite, Dike mountain.
50.59	"	augite-rich lower portion of differentiated sill in Electric peak.
50.29	"	gabbro-porphyry, Deer creek.
50.06	"	shoshonite.
49.71	"	absarokite.
48.95	"	absarokite.
48.73	"	kersantite sill, Bighorn pass, Gallatin mountains.
48.36	"	absarokite.
47.32	"	leucite-absarokite.
47.28	"	leucite-absarokite.

The range in silica is the same as that of the commoner rocks of the Absaroka range, but the alkalies are notably higher than in the other rocks of this region, and the potash is much higher in proportion to the soda. There is a decided decrease in alumina in the less siliceous rocks. Lime, magnesia and iron oxide are lower than in rocks of the Absaroka and Gallatin series with corresponding amounts of silica, especially in those with more than 54 per cent. The highly differentiated condition of the rocks with less than 54 per cent. of silica is shown in the diagram. Those with high magnesia and femic lime are mostly absarokites. It is interesting to note that the differentiated sill in Electric peak belongs in this series. The lower portion of this sill is rich in augite phenocrysts and has a chemical composition similar to that of some absarokites, while the upper portion has the chemical composition of some banakites. Hence this sill shows the differentiation in place of a magma into varieties of rocks similar to those occurring as separate lavas in other parts of the region.

The study of the rocks of the Yellowstone National Park region shows that from magmas characterized by lime-soda feldspars in most instances, but which differ somewhat in the western and eastern districts in the relative amounts of potash and soda, of total alkalies, and of calcic feldspars, there have been differentiated, at different times and in various places, subordinate amounts of magmas relatively richer in alkalies and stronger in potash. These varieties are mostly subsilicic, but are in some instances intermediate in silicity. In the least siliceous varieties, leucite appears among the mineral constituents, and in several others its presence has been suspected, but has not been actually determined.

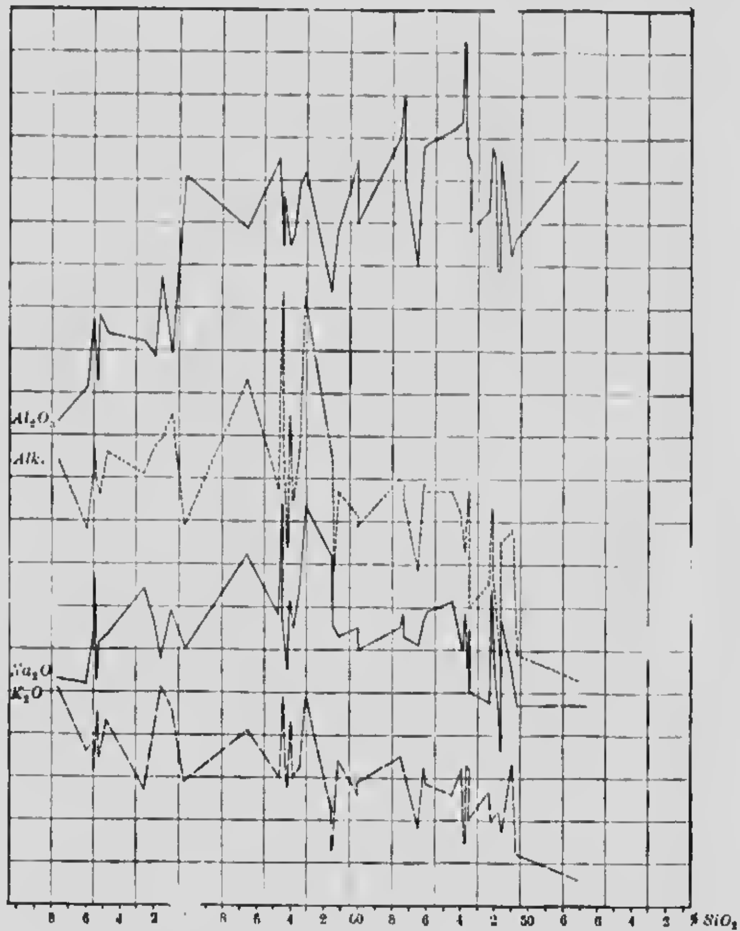

FIG. 3.—Molecular proportions of alkalies and alumina in igneous rocks of the Absaroka range, Yellowstone National Park.

About 80 miles north of this region, in the Crazy mountains, Montana, there is a series of intrusive rocks that occur in a large stock surrounded by innumerable sills and dikes, and fewer out-lying sills, dikes and small laccoliths. The district has been studied in great detail by Professor J. E.

Wolff,[1] and to some extent by Mr. W. H. Weed and the writer of this paper. The rocks of the stock are diorites with granite, gabbro and some picrite; the sills and dikes immediately surrounding the stock consist of corresponding porphyries, while the outlying bodies are tinguaites, syenites

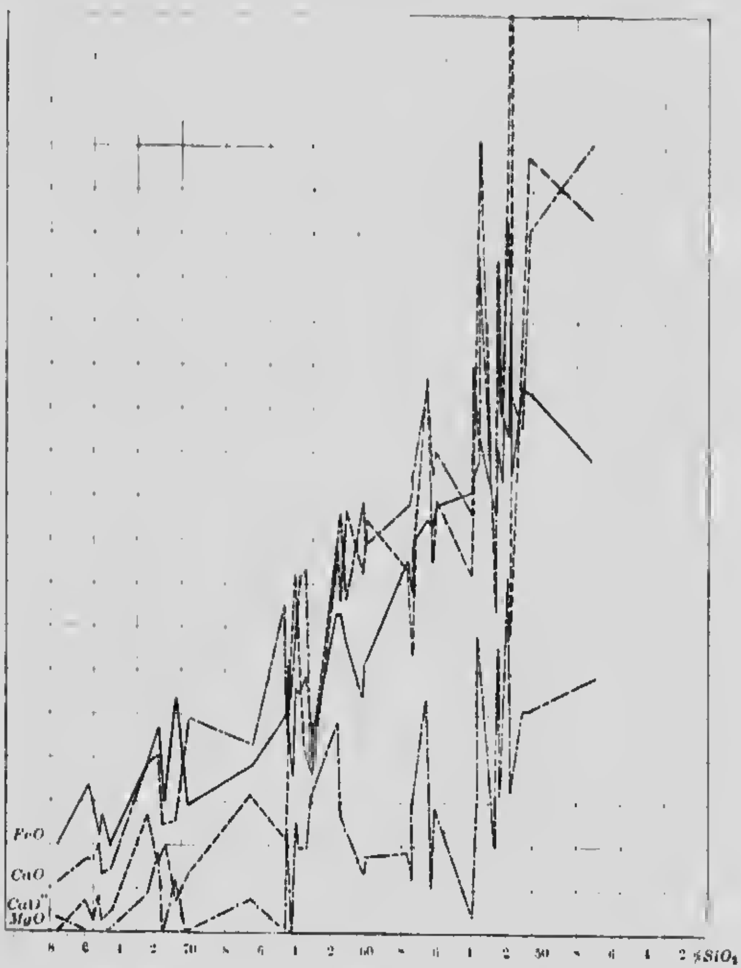

Fig. 4.—Molecular proportions of magnesia, lime and iron oxide in igneous rocks of the Absaroka range, Yellowstone National Park.

and shonkinites, formerly called theralites. The chemical composition of the dominant rocks is closely similar to that of the dominant rocks of the Absaroka range, but the subordinate rocks in the outlying bodies are richer

[1] Wolff, J. E., and Tarr, R., Bull. Mus. Comp. Zoöl., Vol. XVI, No. 12, 1893.

in alkalies with relatively higher soda than potash. Some varieties are higher in alumina. Here again, there have been differentiated from a magma characterized by lime-soda feldspars subordinate amounts of magmas richer

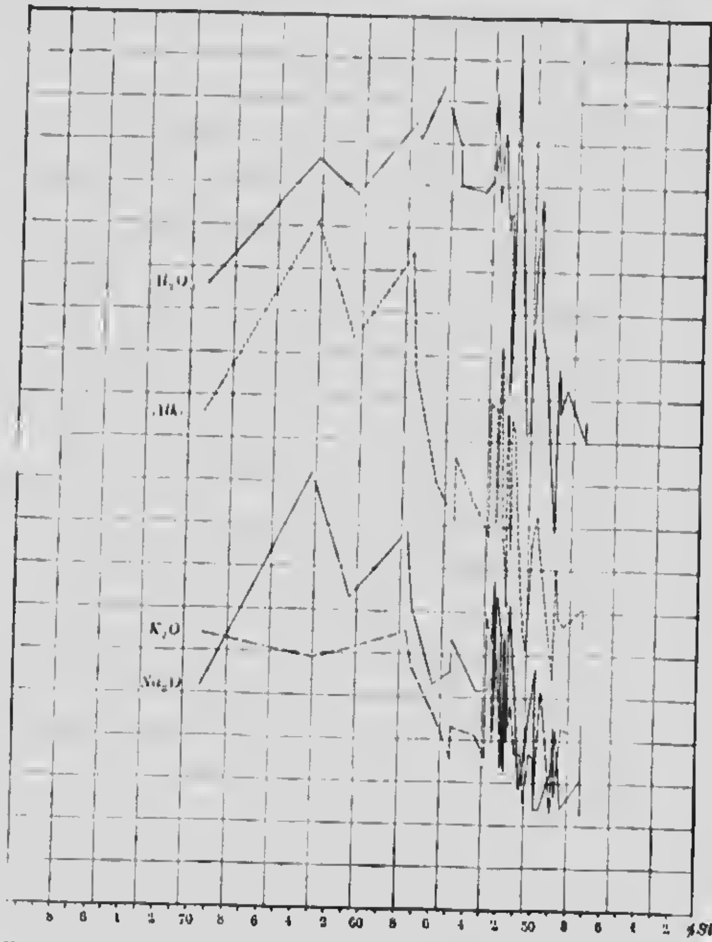

FIG. 5.—Molecular proportions of alkalies and alumina in banakites, shoshonites and absarokites, Yellowstone National Park.

in alkalies, but in this instance with still higher soda than potash, and yielding tinguaites, nephelite-bearing syenites, and shonkinites.

Still farther north, in the Highwood and Bearpaw mountains, there are igneous rocks described by Professor L. V. Pirsson[1] that are characterized

[1] PIRSSON, L. V., and WEED, W. H., Am. Jour. Sci., 4th Ser., Vol. I, 1896, pp. 283 and 351; Vol. II, 1896, pp. 136, 188 and 315; Vol. XII, 1901, p. 1; U. S. Geological Survey, Bull. 237, 1905.

by very high alkalies and specially high potash. The chemical variations of this series of rocks are shown in Figs. 7 and 8, and the list of rocks is as follows:

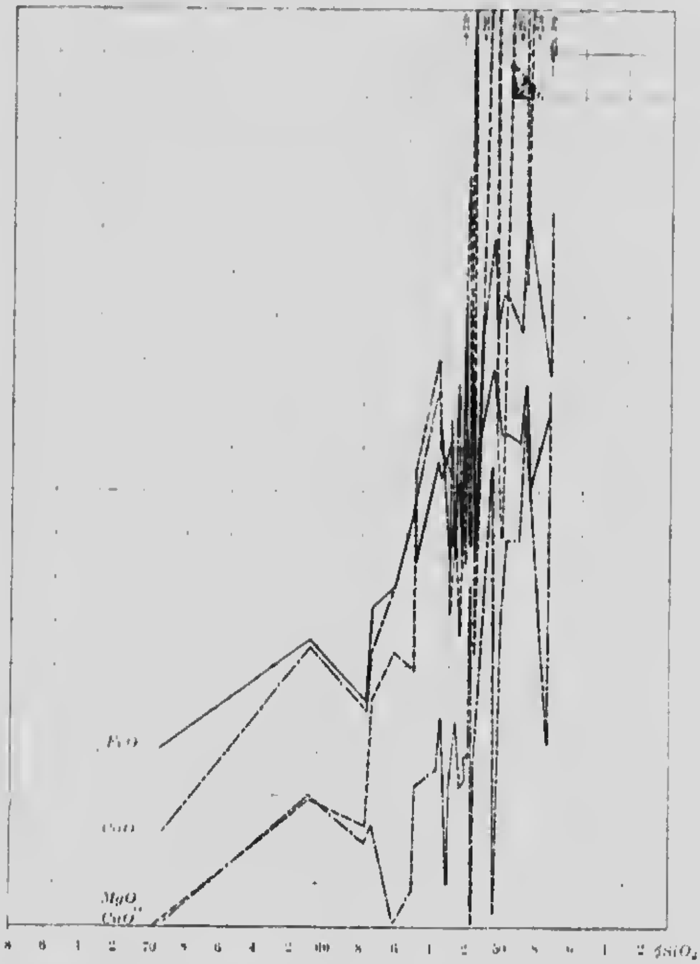

Fig. 6. Molecular proportions of magnesia, lime and iron oxide in banakites, shoshonites and absarokites, Yellowstone National Park.

68.34%	SiO_2	quartz-syenite.	57.46%	SiO_2	tinguaite.
66.22	"	quartz-syenite-porphyry.	57.18	"	tinguaite-porphyry.
			56.45	"	sodalite-syenite.
59.24	"	trachy-andesite.	55.23	"	gauteite.
58.04	"	tinguaite-porphyry.	52.81	"	monzonite.
57.46	"	tinguaite-porphyry.	52.05	"	syenite.

51.94% SiO_2.	syenite-porphyry.	49.59% SiO_2.	leucite-shonkinite.
51.93 "	pseudoleucite-sodalite-tinguaite.	47.98 "	leucite-basalt.
51.75 "	fergusite.	47.88 "	shonkinite.
51.00 "	monzonite.	47.82 "	analcite-basalt.
50.11 "	syenite.	46.51 "	leucitite.
50.00 "	shonkinite.	46.06 "	missourite.
		46.04 "	mica-basalt (*cascadose*).

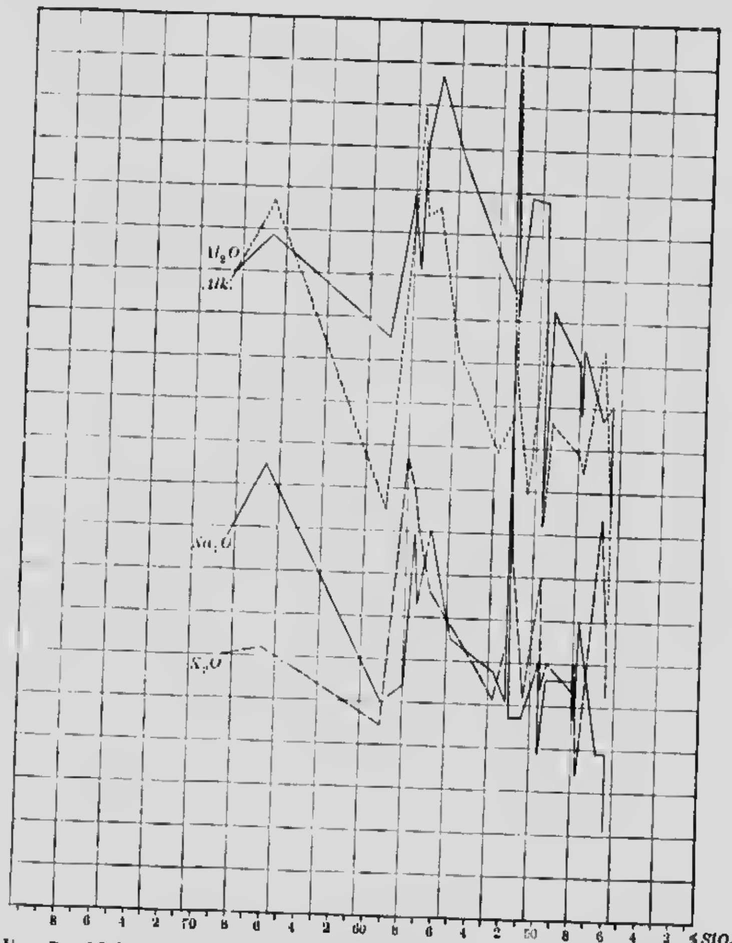

FIG. 7.—Molecular proportions of alkalies and alumina in igneous rocks in the Highwood and Bearpaw mountains, Montana.

In these rocks the total alkalies are nearly equal to the alumina in most instances and exceed it in several rocks. A comparison of Fig. 7, with Figs.

1 and 3, shows a striking contrast between the rocks of this district and those of the Yellowstone National Park region with respect to alkalies and alumina, and consequently with respect to the salic lime which may enter anorthite molecules. There is some resemblance between Figs. 7 and 5, of the banak-

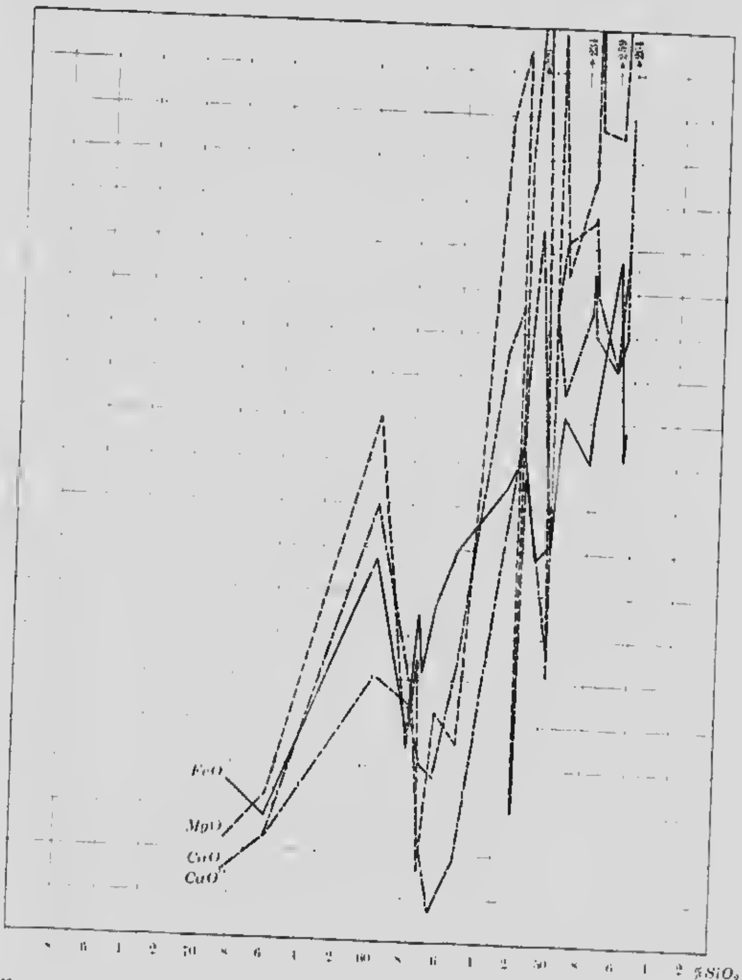

FIG. 8.—Molecular proportions of magnesia, lime and iron oxide in igneous rocks in the Highwood and Bearpaw mountains, Montana.

ites, shoshonites and absarokites in the relation of the alkalies to one another, but the potash is not so high as the soda in most of the banakites, shoshonites and absarokites, though nearly equal to it, and the total alkalies are noticeably lower in the less siliceous rocks of this series. The lime, magnesia and iron oxide in the rocks of the Highwood and Bearpaw mountains have a very similar range to that of these constituents in the banakite-shoshonite-absarokite series, except for certain pronounced cases of differentiation with very low lime, which have produced tinguaites and syenites, and for the fact that the femic lime is nearly equal to the total lime in most instances and is equal to it in a few rocks.

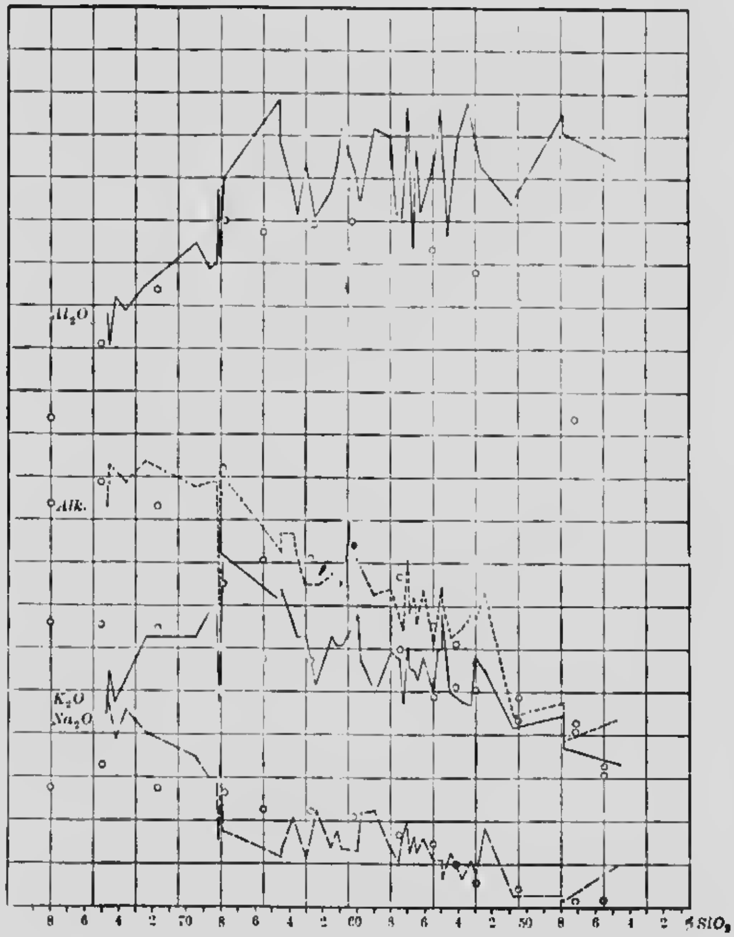

FIG. 9 —Molecular proportions in alkalies and alumina in lavas of the Lassen-Shasta district, California.

From the foregoing considerations it is evident that the occurrence of subordinate amounts of rocks that are somewhat richer in alkalies than the normal varieties of the series in which they belong is to be interpreted as an instance of special differentiation dependent on special conditions attendant on eruption. Further, the chemical character of the parent magma is to be estimated from the average of the whole series, of which the exceptional rocks may be quite subordinate parts. Moreover, the fundamental char-

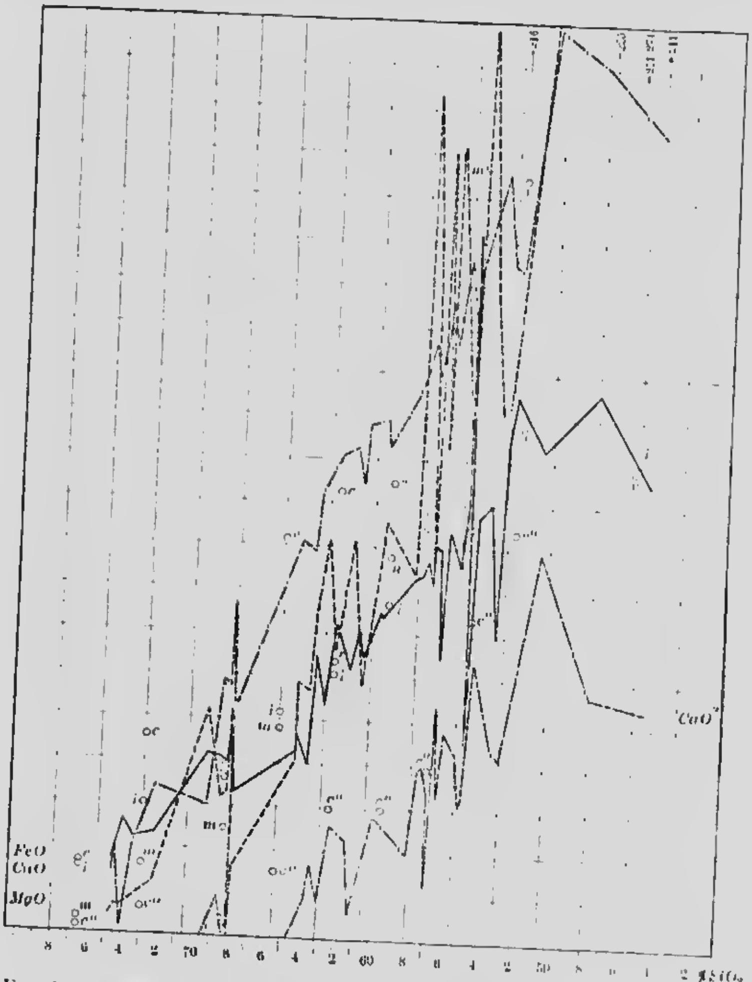

FIG. 10.—Molecular proportions of magnesia, lime and iron oxide in lavas of the Lassen-Shasta district, California.

acteristics of petrographical provinces are dependent upon the preponderant or average magma, not on subordinate phases of its differentiated varieties.

Series of lavas erupted at different periods within one region may experience somewhat different physical conditions during eruptive activity, and may attain somewhat different degrees of differentiation. Or those bodies of lava intruded within the lithosphere may be more highly differentiated than other bodies that reached the surface and were extruded. Examples of such differences are to be found in the series of intrusive rocks in the Sierra Nevada range and in the extrusive lavas of Lassen peak and Mount Shasta and vicinity in California.

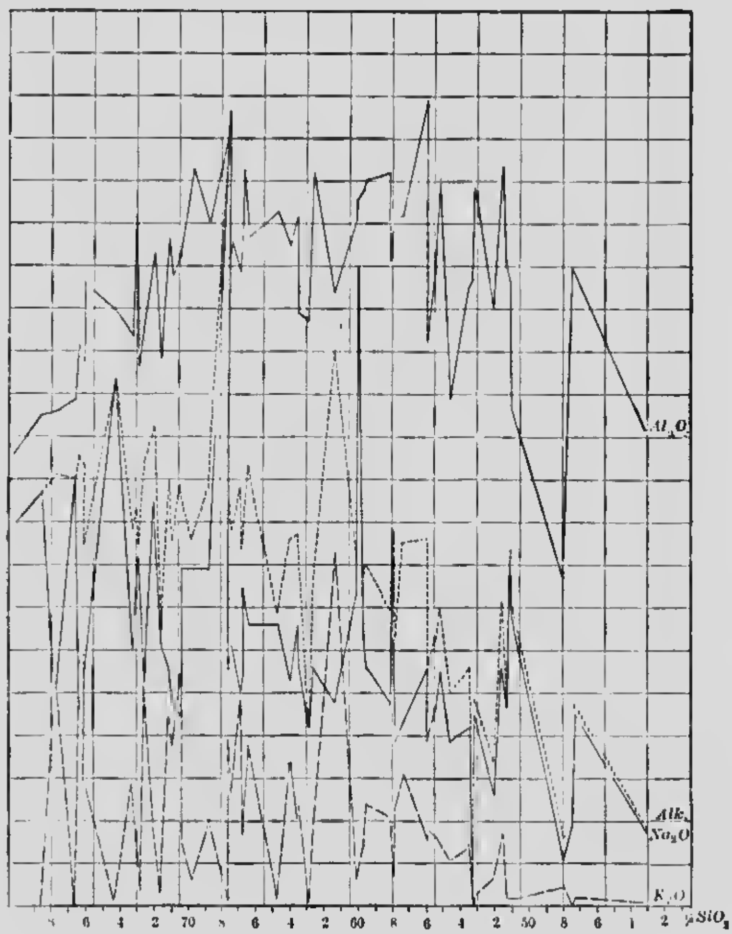

FIG. 11.—Molecular proportions of alkalies and alumina in intrusive rocks of the Sierra Nevada, California.

The lavas of the Lassen-Shasta district have been studied by Mr. J. S. DILLER[1] and are rhyolites, dacites, various andesites, quartz-basalts and

[1] DILLER, J. S., U. S. Geological Survey, Bull. 79; Bull. 150, in part; and Bull. 419, p. 135; also Am. Jour. Sci., 3rd Ser., Vol. XXXIII, 1887, p. 49.

normal basalts; they range in silica from 74.65 per cent. to 44.77 per cent. as follows:

74.65% SiO_2, rhyolite.
74.60 " rhyolite.
74.24 " ryholite.

68.32% SiO_2, dacite.
68.20 " dacite.
68.10 " dacite.

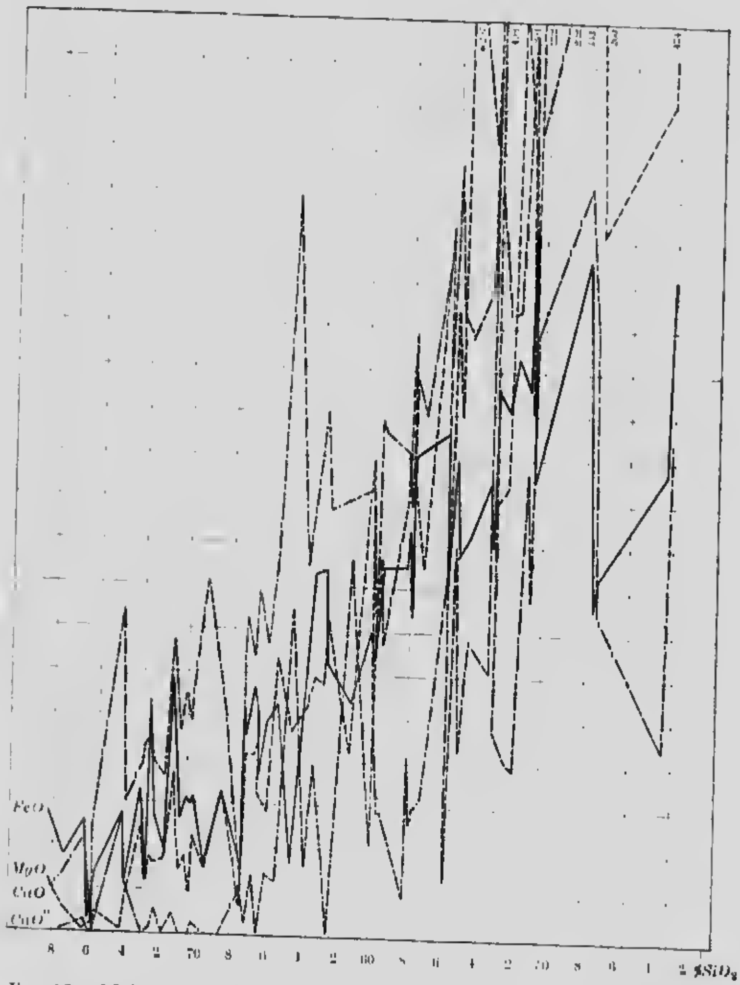

FIG. 12.—Molecular proportions of magnesia, lime and iron oxide in intrusive rocks of the Sierra Nevada, California.

73.62% SiO_2, rhyolite.
72.40 " rhyolite.
69.51 " dacite.
68.72 " dacite.

68.12% SiO_2, hypersthene-andesite.
67.89 " hornblende-andesite.
64.48 " hornblende-andesite.
64.52 " hypersthene-andesite.

63.81%	SiO_2,	dacite?	56.70%	SiO_2,	quartz-basalt.
63.47	"	hypersthene-andesite.	56.51	"	quartz-basalt.
63.03	"	hypersthene-andesite.	56.18	"	quartz-basalt.
62.44	"	pyroxene-andesite.	55.53	"	hypersthene-andesite.
61.58	"	pyroxene-andesite.	55.20	"	hypersthene-andesite.
61.17	"	hypersthene-andesite.	55.08	"	secretion in dacite.
60.93	"	hornblende-andesite.	54.56	"	quartz-basalt.
60.04	"	hornblende-andesite.	53.85	"	secretion in hypersthene-andesite.
59.84	"	hypersthene-andesite.			
58.08	"	hypersthene-andesite.	52.95	"	basalt.
57.59	"	quartz-basalt.	52.63	"	basalt.
57.25	"	quartz-basalt.	50.89	"	basalt.
57.11	"	hypersthene-andesite.	47.93	"	basalt.
57.04	"	secretion in hypersthene-andesite.	44.77	"	hornblende-basalt.

In Fig. 9 are shown the variations in potash, soda and alumina in the Lassen-Shasta series, and in Fig. 10 the variations in lime, magnesia and iron oxide of the same series. The contrast between Fig. 9 and the corresponding Figs. 1 and 3, of the Yellowstone National Park series is striking. The Lassen series is very low in potash, and is lower in soda and the total alkalies than the Yellowstone Park rocks, whereas the alumina averages a little higher. That is, the proportion of anorthite molecules to albite and orthoclase molecules is greater than in the Yellowstone National Park rocks; and though the rocks of the two regions are named alike, the chemical distinctions between the two series is pronounced. Fig. 10 shows an equally characteristic difference in the proportions of the lime, magnesia and iron oxide. Total lime is noticeably greater than magnesia in rocks with more than 58 per cent. of silica, and in half of the less siliceous rocks analyzed the iron oxide and magnesia are markedly variable, especially in the less siliceous rocks. The iron oxide is noticeably lower than the magnesia, and the femic lime is strong.

The intrusive rocks in the Sierra Nevada have been described by Professor W. LINDGREN[1] and Mr. H. W. TURNER.[2] The variations in their chemical constituents are shown in Figs. 11 and 12. The highly differentiated character of this rock series is indicated by the marked differences in the amounts of potash and soda in rocks with nearly the same silica, in the marked changes in the total alkalies, and in the irregularities in the alumina, lime and other constituents. A list of the analyzed rocks follows:

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[1] LINDGREN, W., U. S. Geological Survey, Fourteenth Annual Report, 1894, p. 284; Seventeenth Annual Report, 1896, pt. 2, p. 1; Am. Jour. Sci., 4th Ser., Vol. III, 1897, p. 306.

[2] TURNER, H. W., U. S. Geological Survey, Fourteenth Annual Report, 1894, p. 437; Seventeenth Annual Report, 1896. pt. 1, p. 521; Jour. Geol., Vol. IX, 1901, p. 507.

78.50% SiO_2, granite-porphyry.
77.68 " granitite.
76.52 " granite-porphyry.
76.26 " alaskite.
76.03 " granulite (aplite).
76.00 " granite.
75.97 " granulite (aplite).
74.32 " granite-porphyry.
74.21 " soda-granulite (aplite).
73.18 " micropegmatite.
73.00 " granite.
72.77 " dacite.
72.48 " granite-porphyry.
71.88 " soda-granite-porphyry.
71.48 " monzonite.
71.08 " biotite-granite.
70.75 " quartz-monzonite.
70.43 " quartz-monzonite.
70.36 " granodiorite.
69.66 " diorite.
68.65 " biotite-quartz-monzonite.
67.53 " soda-syenite-porphyry.
67.45 " granodiorite.
67.33 " granodiorite.
66.83 " hornblende-biotite-granite.
66.65 " quartz-diorite-porphyry.
66.65 " granodiorite.
66.28 " granite.
65.54 " granodiorite.
64.67 " quartz-diorite.
63.85% SiO_2 granodiorite.
63.43 " granodiorite.
62.77 " inclusion in monzonite.
62.62 " quartz-mica-diorite.
61.28 " augite-syenite.
60.09 " camptonitic dike rock.
60.00 " soda-syenite.
59.68 " grandiorite.
59.48 " granodiorite.
58.09 " quartz-mica-diorite.
58.05 " diorite.
57.87 " diorite.
57.80 " quartz-pyroxene-diorite.
57.26 " quartz-mica-diorite.
55.87 " gabbro.
55.86 " diorite.
55.40 " gabbro.
55.18 " diorite-porphyry.
54.64 " quartz-diorite.
53.46 " diorite.
53.25 " diabase.
53.19 " diabase.
52.55 " quartz-hornblende-diorite.
52.06 " diabase.
51.32 " diabase.
51.07 " uralite-diorite.
51.01 " diabase.
48.04 " amphibole-pyroxenite (perknite).
47.49 " gabbro.
47.27 " amphibole-gabbro.
43.41 " olivine-gabbro.
43.17 " amphibole-picrite.

A general resemblance between the proportions of constituents in this series of rocks and those in the rocks of the Lassen-Shasta district is apparent at a glance, but the essential identity of the parent magmas from which each series differentiated is demonstrated by reducing the highly irregular lines in Figs. 11 and 12, to average lines and plotting the points so found in the diagrams of the less differentiated series from the Lassen-Shasta district. This has been done in Figs. 9 and 10. In this way it is seen that the lines for the total and several alkalies in each series are nearly coincident, while those for the alumina are nearly so in the more siliceous half of the two series, but differ considerably in the subsilicic end, where there are few analyses and where there are several extremely femic differentiates in the intrusive series, as is shown in Fig. 12. The correspondence between the average lime, magnesia and iron oxide in the Sierra Nevada series and the same constituents in the Lassen-Shasta series is close in all but the subsilicic end of the two series, in which the few intrusive rocks analyzed are much richer in these constituents than are the basalts of the Lassen-Shasta district.

From these chemical similarities it may be concluded that the two series of rocks were derived by processes of differentiation from magmas having strong chemical resemblances, that is, they appear to be isomagmatic, possibly comagmatic. Furthermore, it appears that the lavas intruded in late Cretaceous times in the Sierra Nevada were more highly differentiated than those erupted in late Tertiary times in the Lassen-Shasta district, especially with respect to the separation of soda and potash in the more siliceous intrusive rocks, and in the production of highly femic rocks in the subsilicic end of the series.

The bearing of these relationships and contrasts upon the problem of petrographical provinces is obvious. They show that quantitative and characteristic differences may exist between the rock series of regions whose rocks may bear like names according to customary mineralogical definitions; also that there may be gradational variations or differences between the rock series of neighbouring districts or regions, a condition which PIRSSON has called a "regional progression of types." Moreover, in some instances small amounts of magma may be differentiated which may crystallize into rocks containing leucite, nephelite, or sodalite, and these subordinate lavas in one district may resemble closely the preponderant lavas in another. Finally, it is evident that there must be many varieties of parent magmas in various parts of the earth, and not merely two distinct kinds, as frequently intimated in discussions of petrographical provinces. It should be the object of petrographical research to discover as nearly as possible the chemical composition of the rock series in all regions investigated.

THE VOLCANIC CYCLES IN SARDINIA.

BY

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INTRODUCTION.

In the autumn of 1905 I had the opportunity to study the volcanoes and igneous rocks of Sardinia for the Carnegie Institution of Washington. It is not the present purpose to describe these petrographically and in detail, (which will be done in a series of papers now in preparation), but to state briefly some of their general petrological features and relationships, with the bearing of these on certain phases of magmatic differentiation. Analyses selected from many already made by me are given to show the chemical composition of some of the more important and typical rocks.

The igneous rocks of Sardinia, first made known to us in 1857 by the classic and monumental work of De La Marmora, have been studied recently by Bertolio, Dannenberg, Serra, Deprat, and Millosevitch.

THE THREE CYCLES.

Through the work of these geologists, confirmed by my own observations, it appears to be clear that the Cenozoic volcanoes of Sardinia belong to at least three volcanic cycles, to use the term introduced by Geikie, denoting recurrent periods in the history of a volcano, in which the progressively changing composition of the lavas repeats itself more or less perfectly and completely. It is also evident that all these lavas are related and are comagmatic, that is, derived from the same general "magma basin," assumedly by processes of differentiation.

The first cycle consists of extensive flows which cover a large part of northwestern Sardinia. The earliest of these are of rhyolite, and are intercalated with rhyolitic tuffs and Tertiary (Oligocene?) marls. These sheets are very extensive, 5 to 15 metres thick, and for the most part dip gently to the northwest. A typical analysis is shown in A of the table on page 231.

These rhyolites are overlain unconformably by thinner, horizontal sheets of so-called "sheet basalts," which are apparently also of Tertiary age. These so-called "basalts" vary very much in character, and are in reality dacites, trachytes, latites, andesites, and feldspar-basalts, a marked characteristic of the last two being the common presence of hypersthene. (Analyses B, C, D.)

The sequence of these flows as given by DEPRAT, and confirmed by my own observations is: (1) rhyolites; (2) trachytes, andesites, and latites; (3) basalts. Most, if not all, of these flows appear to have issued from fissure eruptions. This is certainly true of the earlier ones, though DEPRAT thinks that some of the basalts are connected with huge volcanic cones. My observations were not extensive enough to decide this point but, so far as they went, were adverse to this view.

The second cycle is that of the two large volcanoes of Monte Ferru and Monte Arci, both of which are near the centre of the western coast. The former has been studied by DOELTER, DANNENBERG, and DEPRAT, but Arci seems to have been undescribed since the time of DE LA MARMORA. The age of these volcanoes is somewhat uncertain, but later than the flows just spoken of. They probably began in late or post-Miocene time and continued well into the Pliocene or even into the Quaternary. There is reason for believing that Arci is somewhat the older of the two, though their eruptions may well have been contemporaneous in part.

Both volcanoes are of the same, domal type. Arci, whose lavas cover an area of some 500 square kilometres, formed first a dome about 800 metres high, built up of sheets of rhyolite (Analysis E) and obsidian. The composition of these is much like that of comendite. These were followed by trachytes (F), andesites (G), and probably phonolites, the exact order of these being as yet unknown. The sub-cycle closed with the eruption of extensive flows of basalt (H).

Similarly, Monte Ferru, (with an area of some 700 square kilometres) began with trachytes (I), followed by phonolites (J), which built up a dome about 1,000 metres high. Some of the augitic trachytes contain a little soda-lime feldspar, as does the one whose analysis is given, but the majority carry no plagioclase and much resemble the phonolites, which contain about 10 per cent. of nephelite and a little ægirite. These were followed by small outpourings of a trachydoleritic lava After a pause enormous quantities of feldspar-basalt were poured out, which covered the trachytic dome and extended far over the surrounding country. The cycles and volcanic activity closed with the ejection of very small flows of a so-called leucite-basanite.[1] (Analysis L).

The third and last period is that of the small, recent scoria cones and their flows of the districts of Logoduro and Ozieri, which DE LA MARMORA well called the Sardinian Auvergne. These are generally very fresh and well preserved, and are evidently of very recent geological age, though they antedate human occupation, as some of the prehistoric buildings called *nuraghe* are built on these flows. These lavas are uniformly feldspar basalt, some with and some without olivine, and of rather uniform chemical composition, (M, N, O, P), though there are also met with small amounts of "leucite-basalt" similar to those of Ferru. No definite sequence has, as yet, been made out among them.

[1] Three analyses of these rocks show that the leucite-like mineral is sodic and is probably analcite. They are at present being studied.

ANALYSES OF SARDINIAN LAVAS.

	Early Flows.				Monte Arci.				Monte Ferru.				Recent Cones.			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
SiO_2	72.05	59.92	56.60	49.00	73.09	65.94	56.34	52.79	58.43	60.43	52.40	44.[illegible]5	53.48	52.67	49.78	49.05
Al_2O_3	13.07	14.30	16.80	15.63	13.80	16.11	13.95	16.45	18.58	18.35	15.26	12.55	13.59	15.35	13.37	12.88
Fe_2O_3	2.93	7.50	2.52	4.03	1.28	2.56	1.94	2.74	3.00	1.64	0.74	3.33	1.78	3.82	2.16	2.04
FeO	0.39	0.42	5.12	5.00	0.68	0.82	6.73	6.44	1.22	0.91	8.33	5.30	8.30	5.42	7.51	6.87
MgO	0.66	0.72	3.80	7.86	0.37	0.60	6.41	5.56	0.13	0.1	7.45	10.27	5.88	4.40	7.61	8.20
CaO	1.30	1.90	7.29	8.16	0.69	1.06	6.20	6.51	3.50	1.41	7.33	8.32	7.20	5.91	7.95	6.96
Na_2O	3.49	5.32	2.43	3.93	3.77	5.27	3.10	3.64	4.78	6.15	3.54	4.77	4.38	4.50	4.72	3.42
K_2O	4.55	5.77	1.98	2.60	5.36	6.49	0.76	1.21	5.82	8.68	0.99	0.72	1.02	2.68	2.37	3.81
H_2O+	0.59	2.49	1.80	0.13	0.60	0.25	1.04	1.02	0.94	0.62	0.29	2.01	0.79	0.37	0.34	1.93
H_2O-	0.24	0.34	0.58	0.18	0.72	0.36	0.63	0.21	1.63	0.34	0.06	0.95	0.11	0.14	0.08	0.32
TiO_2	0.40	0.87	0.99	3.25	0.38	1.21	2.22	2.64	1.11	0.36	3.12	5.07	2.52	4.04	3.11	3.75
ZrO_2	0.05	0.11	....	....	0.02	....	....	....	0.24	0.21	....	....	0.59	....	....	....
P_2O_5	0.22	0.58	0.12	0.63	0.07	....	0.44	0.39	0.19	tr.	0.49	1.17	....	0.75	0.72	0.65
SO_3	0.18	0.06		....	none	....	....	...	0.11	0.22	....	....	....	....	....	.
NiO	....	....	....	....	....	....	....	0.18	....	..	0.06	0.23	..	none	....	....
MnO	0.04	0.08	0.13	....	tr.	0.0[illegible]	....	0.06	0.09	0.16	0.08	0.07	....	tr.	....	....
BaO	0.06	0.05	....	....	none	....	....	....	0.14	0.08	....	....	....	....	....	....
SrO	....	....	....	....	....	....	....	....	0.06	0.02	....	....	....	....	....	
	100.22	100.30	100.16	100.40	100.83	100.73	99.79	99.84	99.97	99.75	100.14	99.60	99.64	100.05	99.71	99.88

A. Rhyolite, toscanose (I.4.2.3). Macomer.
B. Trachyte, ilmenose (II.5.1.3). Monte Muradu, near Macomer.
C. Andesite, bandose (II.4.4.4.). Monte Pischinale, near Bosa.
D. Basalt, camptonose (III.5.3.4). Tres Nuraghes.
E. Rhyolite, liparose (I.4.1.3). Near Marubbiu, Monte Arci.
F. Trachyte, phlegrose (I.5.1.3). Conca Cannas, Monte Arci.
G. Andesite, tonalose (II.4.3.4). Canale Perdiera Monte Arci.
H. Basalt, andose (II.5.3.4). Uras, Monte Arci.

I. Trachyte, pulaskose (I.5.2.3). Cuglieri, Monte Ferru.
J. Phonolite, phlegrose (I.5.1.3). Monte Tinzosu, Monte Ferru.
K. Basalt, camptonose (III.5.3.4). Cuglieri. Monte Ferru.
L. "Leucite-basalt," scanose (III.6.2.5). Scano, Monte Ferru.
M. Basalt, camptonose (III.5.3.4). Monte Austida, near Torralba.
N. Basalt, akerose (II.5.2.4). Monte San Mateo, near Ploaghe.
O. Basalt, monchiquose (III.6.2.4). Monte Cucuruddu, near Keremule.
P. Basalt, lamarose (III.5.2.3). Monte Boes, near Pozzo Maggiore.

THE GENERAL RELATIONS.

Sixteen of the analyses made by me are given in the table annexed. Taken as a whole the rocks and the several constituents vary within very wide limits, it being scarcely necessary here to point these features out. But, arranged as they are according to the volcanic cycles and their sequences, they offer some points of interest.

It is, in the first place, clearly manifest that there is a sequence which is discontinuous but recurrent, and that the successive cycles show distinct similarities as well as a marked progressive change. The first two, (or three, counting Arci and Ferru separately) begin with persalanes—the most salic and silicic magmas,—and become successively more femic with decreasing *silicity* and with concomitant variations in the other constitutents. They end in each case with extensive flows of andose or camptonose, that is almost wholly salfemic and of quite uniform composition.

If is, furthermore, noticeable that there is an apparent progressive decrease in differentiation, which is marked in two ways. The cycles show, on the whole, a progressive narrowing of the limits between the extremes of the several components. This is most obvious in the silica, but examination will show it to be true of nearly all the components. Attention may also be called to the decrease in potash relatively to soda as the cycle proceeds. Other similar points will be discussed later in connection with a much greater number of analyses.

The cycles also show a progressive diminution in the number of rock types and intermediate members. The variety of rocks among the early flows is very great, that at Arci less, at Ferru still less, and in the last cycle the rocks are almost uniformly basalts. The first of these features is fairly evident from the analyses given, but the second can best be seen from study of the specimens and the additional analyses not given here.

Attention may be especially called to two points in these relations: the closing of each cycle and of the succession of cycles with feldspar-basalts of the general composition of andose (II.5.3.4) and camptonose (III.5.3.4); and the occurrence together, even at the same volcano, and in commensurate amounts, of what would be called by some petrologists alkalic rocks of the Atlantic tribe and sub-alkalic rocks of the Pacific tribe.

Adequate data are not at hand for even a tentative discussion of the average magmas, since there would be needed very detailed knowledge of the relative volumes as well as many more analyses. But it may be said that the average compositions of the successive cycles, so far as they can be approximately estimated, seem to vary very much in the same way as does the [illegible]st complete cycle.

THE SEQUENCE OF TYPES.

The order in time of successive intrusions or lava flows has always been a subject of deep interest to petrologists, and has given rise to much discussion and a large literature. It is generally assumed that it is connected with processes of differentiation. The subject has been summarized most recently by HARKER in his valuable and highly suggestive treatise, *The Natural History of Igneous Rocks*. He concludes that the general plutonic sequence differs from the volcanic, and that the VON RICHTOFEN-IDDINGS law of divergence from an average magma to extremes has a very wide application in extrusive rocks. We have seen that the sequence in Sardinia is quite different from this, and many other instances could be given to which it does not apply, along with many to which it is applicable.

Nearly twenty years ago BRÖGGER called attention to the paucity of data, the difficulties attending the determination of the relevant facts and their interpretation in ascertaining the true sequence at most centres. Even with the great advance in our knowledge, much the same difficulties confront us now and, in the case of volcanic rocks, it cannot be said that any universally, or even generally applicable sequence has been satisfactorily established.

From a survey of the literature, however, two features of general application would seem to hold good. One is that the sequence varies somewhat with the general or average chemical character of the regional magma. the other, that in the great majority of cases, and apparently irrespective of the general magmatic character, the sequence closes with basaltic (salfemic) rocks. A recurrence in volcanic cycles seems also to be very general.

But, after all, it may be questioned whether the sequence of types is really of the great importance usually attributed to it. Its chief significance would seem to be that of giving us a clue to whether the differentiation, (assuming that the sequence is dependent on differentiation), is a continuous or discontinuous process, and what is its general course. But it must be borne in mind that any particular sequence as observed by us would appear to be dependent largely on circumstances and conditions extraneous to the character of the magma or to the course of differentiation, such as the size and form of the hypothetical magma basin, the point at which it is tapped, the amount drained off, the character and amount of the volatile constituents which escape, and the chances which determine the exposure of the rocks to our observation.

The actual products of differentiation and their relative amounts would seem to be of more importance than their sequence; and for this, in practically every case, many more good analyses and a much more detailed knowledge of the relative volumes and geological relations of the several types present than we now have is absolutely indispensable. Half a dozen analyses of specimens collected more or less at random, with no data as to relative amounts, and mostly from recent flows, do not constitute adequate material for study of the petrology, sequence of types, or course of differentiation at any volcano of considerable size, far less of a district, though they are of interest in default of more abundant material when the district is almost or quite unknown.

CORRELATION WITH VOLCANICITY

There is apparent in Sardinia a connection or coincidence of the several cycles with the discontinuity and character of the volcanic activity. This is manifested by the closing of a magmatic cycle simultaneously with the ending of a volcanic phase, and the recurrence of a new one with a change in the manifestation of volcanicity, either in intensity or character or both. A survey of the literature indicates that this is a feature of volcanism which has been overlooked, and that it is of somewhat common occurrence.

A case recently studied by me is Pantelleria, which is to be described in a forthcoming paper. Among others, evidence of such a connection is shown in the Yellowstone Park, the Highwood Mountains, Etna and Vesuvius. From the classic paper by IDDINGS the recurrence of the magmatic cycles coincident with the change in the character of the volcanicity from intrusive to extrusive at Electric Peak and Sepulcher Mountain is clear. Such a connection is also apparent in the Highwoods, as described by PIRSSON, though here the sequence differs from the preceding. At Vesuvius and Etna the evidence is not so clear, owing to lack of data. The numerous analyses of Vesuvian lavas by FUCHS, HAUGHTON, and others deal only with the historical flows of the cone of Vesuvius. There is no good or modern analysis of the lava flows of Somma, though those by PISANI of the ejected blocks, described by LACROIX, are of special interest, as they give evidence of a decided change in the character of the magma, from a dosodic or sodipotassic to a dopotassic composition. The lavas of the well-known and easily accessible Etna are even more imperfectly known. There are less than half a dozen superior analyses of its rocks to be found, and these only of the products of recent eruptions. Yet the early analyses given by VON WALTERSHAUSEN, unsatisfactory as they are, give clear indication of a change in the general magma since the formation of the Val del Bove caldera and the shifting of the eruptive vent.

On the other hand, there are volcanoes where no such correlative magmatic change seems to have taken place. This is the case at Santorini, of whose lavas, both prior and subsequent to the formation of the great caldera, we have analyses by FOUQUÉ and others.[1] Apart from some very subordinate anorthitic lavas, they are very uniform andesites of the general composition lassenose (I.4.2.4.). To test this point I made some years ago three analyses of typical lavas representing different periods of volcanicity. As they are as yet unpublished, it may be of interest to give them in this connection. Their practical identity is obvious.

[1] Mount Pelée, and other Antillean volcanoes, as remarked by LACROIX, whose lavas generally are handose (II.4.4.5), furnish another example.

Andesites of Santorini.

	A	B	C
SiO_2	65.95	65.14	64.87
Al_2O_3	16.96	17.97	16.65
Fe_2O_3	1.36	1.59	1.46
FeO	3.47	3.33	4.21
MgO	1.13	0.95	1.42
CaO	2.42	2.96	2.88
Na_2O	4.60	5.41	5.09
K_2O	3.08	2.18	1.87
H_2O+	0.49	0.11	0.10
H_2O-	0.05	0.02	0.04
TiO_2	1.03	1.12	1.08
P_2O_5	0.23	0.19	0.23
	100.73	100.67	99.82

A. Santorinal lassenose (I.4.2.4), lowest flow, Therasia.
B. Santorinal lassenose (I.4.2.4), Palaio Kaimeni, A.D. 46.
C. Santorinal lassenose (I.4.2.4), Giorgio Kaimeni, A.D. 1869.

Few volcanoes have been studied with sufficient system, completeness, and detail, and also with sufficiently numerous and representative analyses of the lavas of the different volcanic phases, to enable us to decide whether such a connection is general, and whether it is a real, causal one or only coincidental. Several geologists have expressed the view that the type of volcano formed is dependent partly or largely on the composition of the lava, the idea being based chiefly on the relative fusibility and viscosity. The idea here expressed differs from this, but the data at hand do not permit of any proper discussion of the subject. I can only record my belief that the connection is a causal one, the intensity and character of the volcanic manifestation varying in some way with the character of the magma, (including its volatile ingredients).

"ATLANTIC" AND "PACIFIC" TYPES.

The occurrence of "typical alkali rocks" along with dacites and andesites in Sardinia has been briefly noted by HARKER in his book already mentioned. But the studies and analyses of BERTOLIO, SERRA, MILLOSEVITCH, DEPRAT, and mine show that the joint occurrence of rocks of the two tribes on this island is far more pronounced and extensive than Harker supposed from the literature then available. We find here such typically "Atlantic" alkali rocks as rhyolite, comendite, trachyte, phonolite, and phlogopite-bearing "leucite-basanite," along with commensurate amounts of equally typical "Pacific" sub-alkalic dacite, hypersthene-andesite, augite-andesite, and feldspar-basalt. These even occur at the same volcano, as at Ferru and Arci. All these lavas are supposedly comagmatic, that is, derived from the same "magma basin" or differentiates of the same magma, so far as can be judged from present knowledge and criteria; and must have been subjected to the same crustal movements.

Sardinia would therefore seem to belong to neither the one nor the other tribe, but may, with equal reason, be assigned to both. Examples of similar occurrences are multiplying rapidly. The Pacific basin is yielding an increasing number of "Atlantic" rocks in the Hawaiian Islands, Samoa, Tahiti, the Marquesas, Japan, and elsewhere. Highly sodic persalanes and dosalanes are known as a pronounced feature along the extreme western coast of North America.

In the "Pacific" basin of the Ægean sea there have been recently described and analyzed highly sodic rhyolites, keratophyres, and trachytes. Keratophyre, paisanite, bostonite, and tinguaite are found along with malchite, kersantite, diorite, and olivine-basalt in Eritrea, described and analyzed by MANASSE. These are only two of many recent examples which are to be added to the longer known ones of districts which show conjointly rocks of the two tribes, in violation of the theory of HARKER and BECKE.

It, therefore, seems probable that such general characterizations of many regions are premature, based on hastily and incompletely collected material and observations, and on chemical data which are inexact and insufficient for safe generalization. As an instance may be cited VON WOLFF's characterization of Sardinia in his recent *Vulkanismus*: "Sardinien ist mit Ausnahme des andesitischen Siliquamassivs atlantisch." The same author characterizes the Canadian shield as Atlantic, noting the presence of nephelite-syenites and essexites, but neglecting mention or consideration of the much greater extent of anorthosites and other "sub-alkalic" rocks. If most characterizations of volcanic districts, often based on imperfect knowledge or on a few chance specimens collected by a non-geological explorer, are as accurate as these two, surely theories based on them are premature and must be regarded with caution.

As our knowledge of the igneous rocks of the less well known parts of the earth increases, it would appear that their occurrences and mutual relations are more complex than was thought at first. Furthermore, we have but imperfect knowledge of some of the most easily accessible and best known districts and volcanoes. Among these may be mentioned Vesuvius, Etna, the Æolian and Ponza islands, the Euganean hills, the Eifel, Siebengebirge, Kaiserstuhl, Schemnitz, and the Auvergne and Velay volcanoes. Remarkable as it may appear, the analyses of these lavas to be found in the literature are inadequate, as to quality or number, for proper knowledge and description of the localities. Also analyses of the lavas of the many large volcanoes of the Andes are lamentably few.

But so far as they are ascertained, the data at hand seem, to me at least, to indicate that the relations of igneous rocks are too complex to justify reference to only two lines of variation. In doing so we are not sure that we are approaching the facts more closely than when we were content with the old terms "acid," "intermediate" and "basic." We would seem rather to be thus actually drifting away from the true course.

The complexity of the relations in the field, the distribution of rock types over the earth's surface, the clustering of the great majority of several thousand analyses about a few "central" subrangs; toscanose (1.4.2.3), tonalose

(II.4.3.4), andose (II.5.3.4), camptonose (III.5.3.4), and auvergnose (III.5.4.4-5)—as shown by a recent increased collection of rock analyses whose calculation is nearly complete,—all these indicate rather that there is, or has been, but one general earth magma, (at least in the upper part of the crust). This may vary somewhat in composition, but it may be supposed to have given rise, by successive differentiations *in all possible directions*, to the different magmas which characterize different petrographic provinces.

This general or original magma, from which the subsidiary ones are supposed to have been derived, would have a general composition of about tonalose-andose. The exact composition and the course of differentiation may have been changed or complicated to some extent by local causes, such as the assimilation of country rock or even possibly by crustal movements. But these would seem to me to be of minor importance, and their consideration belongs, as yet, to the sphere of speculation.[1]

Differentiation, as has just been said, is supposed to have proceeded in all magmatic directions, influenced and possibly determined by forces and local causes of which we have no present knowledge. Thus there have been produced districts of very different characters, but of the same grade of importance, so that each should be treated with equal consideration. In one place we find rocks which may be spoken of as characteristically sodic, elsewhere potassic, or calcic, or magnesic, or ferrous. There may be mixtures of any two or more of these dominant features. Also in places the hypothetical general magma would seem to have undergone comparatively little change, and this last seems to have been very frequently the case—which would account for the general preponderance of the "sub-alkalic" rocks. It must, however, be constantly borne in mind that our characterizations, apart from the insufficiency of the data spoken of previously, are often subjective, vague and arbitrary, and illogically and inconsistently carried out. Thus, very frequently only one or a few of the chemical or mineralogical components are selected for the basis of characterization and no regard is paid to others which are present in much greater amount. The mere presence of nephelite or acmite is held by many to be sufficient ground to call a district sodic, or that of leucite to call it potassic, though the actual amounts of these may be not more than about one per cent. On the other hand, if the nephelite molecule should enter feldspars as carnegieite, or that of leucite enter biotite with olivine, little or no attention would be paid to them.

It is surely unphilosophic to select one subsidiary magma, as the alkalic, for special contrast with the greatly preponderating "sub-alkalic" magma, and either neglect all separate consideration of other kinds of magma, or cause them to lose their identity by arbitrary incorporation in the "sub-alkalic" tribe. Such a magnesic or calci-magnesic magma as is characteristic of the northern Urals described by DUPARC is surely entitled to as much

[1] In a recent paper SMYTH upholds the derivation of the alkalic rocks from a common sub-alkalic magma by differentiation, suggesting the "mineralizers" and rarer elements as the agency.

special recognition as the sodic magma of southern Norway. It may be true that the potassic, magnesic, and ferrous magmas or districts are even less often found than those which are "sodic," but it is surely true that the theoretical significance or importance of a magma is not dependant on its abundance.

There is no innate reason, so far as we know, why an alkalic magma, (often called so on inadequate grounds), should alone stand in direct contrast with, or be incompatible with, a calcic or sub-alkalic magma. On the contrary there are very good reasons—among them the frequent occurrences of rocks of both types together— for believing that they may be, and indeed are, genetically connected. Nor is there good reason for lumping together intimately, as is usually done, the potassic and sodic magmas, on the ground that soda and potash are both alkalies, for we know that the two elements show, in many respects, very different chemical behaviour.

The reference of all igneous rocks to two tribes seems to be based ultimately on the dualistic tendency of the human mind. This led BUNSEN to formulate his pyroxenic and trachytic magmas, which were long ago shown to be inadequate to explain the facts. Indeed, even now the inadequateness of the two Atlantic and Pacific tribes begins to obtrude itself, since VON WOLFF—himself an upholder of the doctrine—feels called upon, in his recent book, to institute a third tribe (the Arctic) to embrace purely basaltic regions.

CONCLUSION.

To conclude, it may again be urged that our data are far too insufficient for the broadest generalizations, and that any of these must, of necessity, be considered as highly speculative or, at best, but a tentative working hypothesis. Forty years ago the domain of microscopical petrography was entered, for about thirty years the chemical side has been becoming of ever increasing importance, and we are now just entering a new phase of petrology in which physical chemistry will play the leading part. The necessity for modern, exact physico-chemical study of petrologic problems is shown by the fact that, although the principles of SORET and of GOUY and CHAPERON are constantly appealed to as of fundamental importance in discussions of differentiation, yet their experiments have never, to my knowledge, been repeated, although they were made some forty years ago and in accordance with the crude and roughly quantitative methods then prevailing. Similarly the liquation theory of differentiation has been urged by BÄCKSTRÖM and others, but no one seems to have tried experimentally to ascertain if two magmas are, or could be, actually immiscible or not.

With this entrance of physical chemistry and its exact methods, the complexities will be enormous. We are not dealing with two-component or three-component systems, the working out of which in the laboratory, even in the simplest cases, is an affair of many months or years. We shall have to deal with systems in which the components are many, and not only many but in most cases volatile in part—a fact which enormously complicates the problem from any point of view. Furthermore, the conditions involved are such as to be reproducible only with difficulty, if at all, in the laboratory. The petrologist may well stand aghast at the magnitude and complexities of the problems, and the inherent necessity for accurate and detailed knowledge in the investigations, that now confront him.

But for the successful application of physico-chemical research to petrological problems, apart from laboratory work, three factors are essential. One is the recognition of the importance of quantitative relations. Another is the need of adequate chemical analyses of rocks and their minerals, which can scarcely be too good or too numerous. The third is the properly systematic and complete collection of specimens and field data, based on accurate observation, and including the quantitative relations of the rock types. For all these, time—much time—is needed, and the petrologist can best and most surely attain his goal, not by premature generalization on insufficient data, but by collecting absolutely unimpeachable data on which to base future generalizations. Let our motto be: *Festina lente.*

VARIATIONS IN COMPOSITION OF PELITIC SEDIMENTS IN RELATION TO MAGMATIC DIFFERENTIATION.

BY

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The theories which have been held to account for the differentiation of igneous magmas have quite generally proceeded from the idea that facies are developed within a broadly extended reservoir of molten and necessarily highly viscous material—what at the surface of the earth is called lava. To go a step farther back and consider what may have been the variations in composition of the same material in an earlier unfused condition does not appear to have been discussed, perhaps because, either consciously or unconsciously, the idea of a molten substratum beneath the so called "crust" has been before the mind to the exclusion of this other idea. Even in those theories in which the conception of a liquid interior to our planet has been abandoned, the necessity for modifying this basis of many existing theories has not been at once appreciated. We are still a long way from a solution of the particular state of matter within the earth's core, but we may nevertheless aver with some definiteness that in respect to earth rotation, to external solar and lunar attractions, and to the transmission of rapid undulatory motions, the earth's interior behaves like a highly rigid body. Though undoubtedly at an excessively high temperature, the centrosphere, in so far as it may now be studied, behaves as little as possible like fused material under the conditions known to us. If, on the other hand, the earth's core is unfused, it seems necessary to assume that this is because the earth materials are kept "solid" by pressure in accordance with laws known for a limited range and believed to hold outside these limits.

Therefore in seeking an explanation for the known variations in composition of magmas within the same general region, we are warranted in departing from the usual practice and in examining not alone the possibilities of segregation and of other processes of differentiation which can take place subsequent to fusion, but those also which may have characterized the rock materials before their fusion to form magma. *Our problem thus resolves itself pre-eminently into a discussion of the type or types of rock which, through fusion, could yield magmas of known composition under the conditions which are conceived to exist, and what differences of facies of the magma are thereby possible.*

It has long been the custom, when discussing the distribution of volcanoes, to emphasize their intimate connection with mountain ranges, an association which, for large areas and even for entire continents, must be evident to all students of the subject. Yet a keener analysis of the situation has shown that conditions are not the same upon the larger part of the Eurasian continent that they are in the western interior of North America, in eastern Africa, and in various parts of the Atlantic ocean. In these latter regions mountain ranges, strictly so called, are lacking, but in their place we find a mosaic structure of great orographic blocks whose vertical movements have been more or less in relation to lava outflow. In the western United States along the fortieth parallel of latitude,[1] in the great "rift" region of east central Africa,[2] along the great rift west of the Mexican plateau,[3] and in Iceland,[4] all, it will be noted, within the areas characterized by block adjustments of the earth's shell—it has either been noted or would appear that the outflows of lava take place along the margins of relatively uplifted blocks, the extravasated lava finding lodgement upon the low-lying blocks. It is perhaps possible to assume that the energy necessary to overcome the inertia of these blocks in their sudden elevation to the accompaniment of earth shocks has carried them beyond the position of equilibrium, thus bringing about a partial relief from load in some lower level where a fusion of the rock may in consequence occur. Earthquake studies have taught us, however, that such a strained condition must be relieved by pendular after-adjustments accompanying, and presumably causing, the well recognized "aftershocks" that follow all great earthquakes. These after-adjustments may not be completed before a number of years have elapsed. Any maculæ of magma which arise from the relief of pressure should, it would seem, tend to approach the form of films or pans of considerable horizontal extension, which, under the load, should be elevated toward the earth's surface along any passages either already present or likely to be opened by the action of the lava itself. We may defer the discussion of this portion of our subject until after a consideration of the conditions which obtain within the contrasted regions of the mountain arcs.

One of the most valuable generalizations of Professor EDUARD SUESS, based upon his epoch making studies of the earth's face, is that, within the so called "Pacific region," volcanoes lie for the most part in arcs which are parallel to cordilleras or folded ranges and generally upon the concave or inner side. Elsewhere we have shown[5] how this peculiarity of grouping with reference to folded arcs is in harmony with the view that magma maculæ

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[1] CLARENCE KING, *Systematic Geology*, Vol. 1, p. 691, U.S. Exploration of the 40th Parallel, 1878.

[2] ED. SUESS, *Die Brüche des östlichen Afrika*, Denksch. Wiener Akad., Math. Naturw. Kl., Vol. LVIII, pp. 555-584, 1891.

[3] KARL SAPPER, *Ueber die räumliche Verbreitung der mexikanischen Vulkane*, Zeitsch. d. deutsch. geol. Gesell., pp. 574-577, 1893.

[4] TH. THORODDSEN, *Die Bruchlinien Islands und ihre Beziehungen zu den Vulkanen*. Pet. Mit., Vol. LI, p. 3, map pl. 5, 1905.

[5] *Some considerations concerning the place and origin of lava maculæ*, Gerland's Beiträge zur Geophysik, Vol. XII (Heft 2), pp. 329-361, 1913.

arise wherever there is local relief from load through the formation of arches in competent formations. The folded arcs themselves are known to be made up of overturned and "overthrust"[1] beds which dip inward in the direction of the centre of the arc.[2] Wherever competent formations (limestone or dolomite) are present and weaker formations lie below, there will be a tendency for the latter to fuse, provided it is at such a temperature that its materials would melt under reduced pressure. Such a tendency will naturally be the greater in proportion as the beds are weaker and more easily fusible. If lava formed in this way subsequently arrives at the surface of the earth along essentially vertical fissures or shafts, the exuded or ejected masses should appear at vents upon the inner margin of the folded arc whose formation has given rise to the macula or maculae. In this connection it should not be forgotten that there is an intimate association not only in place, but also in time between volcanoes of the "Pacific type" and the mountain arcs to which they belong; the period of elevation of the arc is broadly contemporaneous with the activity of its volcanoes.

The tendency of rock materials to fuse locally and thus to form reservoirs of magma would not appear, therefore, to be essentially different for the "Atlantic" fault block type on the one hand or the "Pacific" volcanic arc type upon the other; since in either case the two properties of structural weakness and of fusibility are the chief ones favouring the formation of maculae.

The pelitic or argillaceous types are so different in both these respects from all other rock formations, either igneous or sedimentary, that they stand in a class by themselves. They are, further, by far the most widely distributed and abundant of all the sedimentary rock formations.[3] It should perhaps, on this account, be less a matter for surprise than it is to find, upon examination of both the average and the individual chemical analyses of argillaceous rocks, and comparison of these with the average and the individual analyses of igneous rocks, that the correspondence is very close. However, this subject has been fully covered in the author's paper,[4] and need not be gone into here. It may, however, be pointed out that even the differences which are noted and seem to be characteristic,— the rather general excess of lime and of sodium in the igneous rocks—is what we should expect to find as a result of the almost certain absorption of CaO from limestones and of Na from the included salt of all sediments which are intercepted along the path of the magma during its subsequent ascent toward the earth's

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[1] The author believes that the mechanics involved in the process of folding require that these be described as *underthrusts* (Cf. *Earth Features and their Meaning*, p. 137).

[2] See particularly the discussion of the structure of the Timor arc by MOLENGRAAFF in the present volume.

[3] VAN HISE's estimate is that the world's sediments consist roughly of 65 per cent pelitic rocks (Mon. 47, U.S. Geol. Surv., p. 940). Others give values as high as 80 per cent.

[4] GERLAND's Beiträge zur Geophysik, Vol. XII, Heft 2.

surface.[1] The water present in pelitic rocks averages nearly three quarts per cubic foot of rock—an amount quite sufficient, when dissociated, to supply both the free and the combined hydrogen of the gaseous emanations of lavas, as well as the oxygen to combine with the sodium of the dissociated salt and to oxidize the sulphur, carbon, and other minor constituents generally present in this type of sediment. The residue of oxygen, by its union with hydrogen as the surface is reached, with little doubt, supplies much of the energy of volcanic eruptions at the same time that it yields the vast quantities of water vapour which are so characteristic of them. It is just because the oxygen derived originally from water has been used up in the oxidizing process that there is an excess of hydrogen and that free oxygen is one of the rarest of the gases present in volcanic emanations. A portion of the free hydrogen is found in combination with the chlorine derived from the common salt yielding hydrochloric acid, and another portion is combined with the oxidized sulphur to yield sulphuric acid, which, though less abundant than hydrochloric acid, is coming to be recognized as an important product in connection with volcanic eruptions.

The view here expressed to account for magma reservoirs by the local fusion of pelitic rock formations within the earth's outer shell, thus does away with all necessity for assuming the existence of so-called juvenile gases which have been supposed to ascend from the earth's centrosphere (possible only upon the assumption of a fluid interior) and give rise to the so-called phreatic explosions,[2] and for the first time it adequately explains why igneous rocks should be so limited in their range of composition, for these limits are those of the pelitic sediments and are therefore to be explained by the sorting processes of wave action and of resulting off-shore currents.

It remains now to determine whether or not the local differences in composition of the argillaceous sediments of any given area are sufficient to account for the observed differentiation of igneous magmas within so-called petrographic provinces. This subject has not been investigated exhaustively, but the comparison with a petrographic province taken at random—that of south central Wisconsin, in which a series of soda aporhyolites is developed at widely different centres—is shown to offer the same measure of difference in composition as does a series of slate analyses from specimens collected in neighbouring townships within the New York-Vermont slate belt. These figures are here reproduced from the author's paper already cited.

Obviously the acceptance of this view of the origin of magma permits of exactly the same assumptions concerning differentiation *subsequent to fusion* as those that belong to the usual basal hypothesis. Its advantage is that those broadly developed facies within a petrographic province, which are sometimes separated from one another by distances of tens of miles and which

[1] DALY has drawn attention to the changes which the absorption of an excess of lime may have upon the separation of melanocratic constituents of the lava so as to yield two contrasted facies, one of which is alkaline and the other sub-basic (*Origin of the alkaline rocks*, Bull. Geol. Soc. Am., Vol. XXI, 1910, pp. 87-118).

[2] ED. SUESS, *The Face of the Earth*, Vol. IV, 1909, p. 568.

it would be extremely difficult to explain by segregational processes taking place within a fused mass, find here both a simple and a natural explanation.

Obviously, the common peculiarities in composition which characterize different portions of the same area of argillaceous sediments may be largely accounted for by the differences in the materials borne by inflowing rivers or derived from wave attack upon neighbouring shores, the material from both sources being distributed and deposited by tides and off-shore currents. To illustrate, such an area of deposition as that lying off the bight centred at New York harbour should yield terrigenous deposits with certain dominant characters and average composition which would be expected to differ from those of deposits at the same depths in the Gulf of Maine or in the bight lying off Chesapeake bay.

These three areas should, upon the other hand, reveal common relationships which should set them off from deposits formed in a different age upon the Atlantic coast when waves were making their attack upon other cliffs and the rivers were bringing down to the sea the ruins of quite different rocks then exposed to weathering and erosion. It may not be without significance that the petrographic provinces of the eastern United States are arranged as broad belts which are roughly parallel to the Atlantic coast.[1]

IGNEOUS ROCKS (APORHYOLITES) FROM PETROGRAPHIC PROVINCE OF SOUTH CENTRAL WISCONSIN.

	Observatory Hill	Marquette	Baraboo	Endeavor	Taylor's Farm	Marcellon	Alloa	Utley
SiO_2	74,46	73,00	71,21	72,80	78,23	79,03	71,14	73,09
Al_2O_3	15,28	15,40	12,20	15,50	11,11	13,23	19,58	13,43
Fe_2O_3	1,95	0,65	1,71	2,01	1,73	0,34	1,25	2,57
FeO	0,74	2,10	5,44	0,60	1,03	0,18	0,88	....
MgO	0,08	0,12	0,13	0,08	Tr.	0,7	0,37	1,03
CaO	0,92	1,74	0,98	0,52	0,28	0,25	2,11	2,29
Na_2O	2,57	4,57	4,29	5,70	3,44	3,95	2,34	3,85
K_2O	3,01	2,01	1,86	2.52	4,08	2,28	2,62	1,58

[1] H. S. Washington, *The distribution of the elements*, Bull. Am. Inst. Min. Eng., No. 23, 1908, pp. 809-838; also in Smith, Rept. for 1909, 1910, pp. 279-304.

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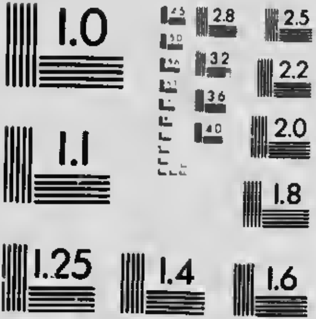

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SLATES FROM DIFFERENT LOCALITIES IN THE VERMONT-NEW YORK SLATE BELT.

	Poultney	Pawlet	Benson	Castleton	Hampton	Granville	Janesville	Raceville
SiO_2	59,27	67,76	59,70	60,96	67,61	67,55	67,89	63,88
Al_2O_3	18,81	14,12	16,98	16,15	13,20	12,59	11,03	9,77
Fe_2O_3	1,12	0,81	0,52	5,16	5,36	5,61	1,47	3,86
FeO	6,58	4,71	4,58	2,54	1,20	1,24	3,81	1,44
MgO	2,21	2,38	3,23	3,06	3,20	3,27	4,57	5,37
CaO	0,42	0,63	1,27	0,71	0,11	0,26	1,43	3,53
Na_2O	1,88	1,39	1,35	1,50	0,67	0,61	0,77	0,20
K_2O	3,75	3,52	3,77	5,01	4,45	4,13	2,82	3,45

DISCUSSION SUR LA DIFFÉRENTIATION DANS LES MAGMAS IGNÉS.

A. C. LANE (Boston) stated that the variation in grain of diabase dikes indicated a superheating at least in the ratio of 1,500° to 1,100°. The stratification of fine clay while yet suspended in water seems to find a parallel in light and dark bands, which appear even in certain large effusions. This banding seemed to be due to a differentiation into layers which are alternately more or less conspicuously feldspathic.

F. LOEWINSON-LESSING (Petersburg): Ich bin der Meinung, eine Fundamentalfrage der Differentiation sei folgende: Genügt die Kristallisationsdifferenzierung für die Erklärung aller Differentiationserscheinungen und der Verschiedenheit der Eruptivgesteine oder ist es erforderlich noch eine, dieser vorangehende, im flüssigen Zustande sich vollziehende Differentiation anzunehmen?

Ohne die Bedeutung der Kristallisationsdifferenzierung für die mineralogische und strukturelle Ausbildung einzelner Magmen abzusprechen, sei es, dass dieselbe sich nach dem eutektikalen oder nach einem andern bei Metallegierungen festgestellten Schema (syntektikal, monotektikal, dystektikal, u.s.w.) sich vollzieht, muss man zugeben, dass die der Kristallisationsdifferenzierung anheimfallenden Magmen bereits Produkte einer im flüssigen Zustande erfolgten Differentiation sind. Dafür sprechen solche Umstände wie die Art der Verknüpfung der monomineralischen Gesteine mit den polymineralischen, die Abwesenheit monomineralischer Gesteine in der Effusivformation, die Identität der Ergussgesteine in ihrer chemischen Zusammensetzung mit den Tiefengesteinen, und die Abwesenheit tiefgehender Differentiation in der Effusivformation. Die Differentiation im flüssigen Zustande dürfte auf eine Entmischung (Liquation, Emulsionsbildung) zurückgeführt werden. Und wenn uns die Silikatschmelzflüsse als unbegrenzt mischbar erscheinen, so haben wir uns nur an die mögliche entmischende Wirkung der fremden eingeschmolzenen Massen, der Chloride, Phosphate, Sulphide, der Gase, u.s.w. zu erinnern, ebenso wie eine homogene Lösung von Essigsäure und Benzol oder Essigsäure und Chloroform durch Wasser, oder eine wässerige Lösung von Isobuttersäure durch Wasser, oder eine wässerige Lösung von Isobuttersäure durch Chloride von Alkalien, oder auch andere alkalische Salze (nach SMIRNOW) zur Entmischung gebracht werden. Aus der Struktur des Endproduktes kann man auf alle Zwischenstadien bei Silikatschmelzen ebenso wie bei Metallegierungen nicht schliessen. Hat sich in einem Magma ein temporärer Gleichgewichtszustand eingestellt und wird er durch Assimilation, durch Druckentlastung, Temperaturwechsel, Gasentweichung oder Gasaufnahme gestört, so kann die Wiederherstellung des Gleichgewichts auf verschiedenen Wegen, auch auf dem Wege der Entmischung in Teilmagmen, erreicht werden.

Die tiefmagmatische Differentiation ist ein im Sinne der Thermodynamik natürlicher Prozess, soweit dieselbe durch Abkühlung bedingt wird. Es muss also das Prinzip der grössten Arbeit, wie es jetzt aufgefasst wird, das Prinzip der Entwertung der Energie, also das Bestreben zur grössten Entropie, der diese Differentiation regelnde Grundfaktor sein.

WHITMAN CROSS (Washington): The differentiation of igneous magmas presents many aspects, according to the point of view. The phase of this problem prominent in my own recent work has been that of the real significance of the current distinction between the so-called alkali and sub-alkali, or alkalic and calcic series of igneous rocks. Are they genetically distinct and worthy of recognition as a natural element in systematic classification, as claimed by ROSENBUSCH and many other petrographers? According to this view the members of the two series may not originate as differentiates from a single parent magma. Indeed, unless this is true, there is no reason for a sharp distinction between the series.

The Hawaiian Islands are a petrographic province of very simple character. The lavas of this province are all consanguinatic, seeming to represent a basaltic parent magma and its derivatives originating by magmatic differentiation. No foreign rocks are known in outcrop or as inclusions except recent coral and mud deposits, and the influence of assimilation of foreign materials need not be considered unless one adopts the view of Dr. DALY that limestone has played a necessary part in the formation of the more alkalic lavas. A careful study of 43 analyses of Hawaiian lavas shows that the average rock of these analyses is a normal basalt of the sub-alkaline or calcic type. Apparently the primary or parent magma from which the more salic and more femic lavas are derived must have corresponded to this average magma.

The lavas range from a feldspar-rich soda-trachyte to very basic basalts of several kinds. The closest analogues of the Hawaiian lavas are distributed all over the world. Fifteen of them are either of pronounced inherent alkaline character or occur in intimate association with rocks of such character. Other analogues are of pronounced calcic composition.

It seems demonstrated that in several, and perhaps in every one of the great Hawaiian volcanoes both alkalic and calcic magmas have been formed by the differentiation of a medium basaltic magma. This is in harmony with the recent studies of LACROIX in Tahiti and Reunion, of WEBER in Samoa, and of WASHINGTON in Sardinia. These, and a host of other instances that might be cited, show that the distinction between alkalic and calcic (Atlantic and Pacific) series, assumed to have a genetic value and made the basis of systematic division by ROSENBUSCH, is, in fact, unnatural.

With regard to hypotheses as to the process of differentiation, I feel that our knowledge as to the facts of the rocks is still very meagre. The physical chemistry of such complex solutions as rock magmas is just beginning to be understood and the processes which may influence magmatic differentiation are perhaps only in part appreciated. Under these conditions it is wise to remember that "a little knowledge is a dangerous thing." Each speculation or hypothesis must be rigorously tested by the application of all germane facts. What seems to satisfy the conditions of our imperfect observations may utterly fail to stand before new light.

J. W. EVANS (London), concurred with the opinion which had been expressed as to the complexity of the factors that determined the differentiation of igneous magmas. He did not therefore wish to minimise the importance of the part played by other agencies when he expressed his belief that the presence of water had an important bearing on the process of differentiation. As was mentioned by Mr. HARKER, experiments appeared to show that molten silicates were miscible in all proportions, and that a melt consisting solely of silicates would not separate into two distinct layers under the action of gravitation.

However, it seemed probable that this might happen if sufficient water were present. Some constituents of igneous rocks, such as quartz, alkali feldspars and muscovite, appeared to be capable of dissolving in water at high temperatures and forming a homogeneous magma. This was evidenced by their occurrence in "pegmatite" veins which, it was generally admitted, owed the coarseness of their texture to slow crystallization consequent to the presence of a large amount of water in the magma from which these veins were formed. This water enabled the magma to retain its fluidity at a comparatively low temperature. Minerals such as augite and olivine never occurred in pegmatites and had apparently no affinity for water at temperatures in the neighbourhood of those at which igneous rocks were found. Experiments had shown that there were liquids which were miscible in all proportions at certain temperatures but on cooling separated into two layers, the lower made up mainly of the heavier and the latter mainly of the lighter liquid. Analogously, silicate magma containing a large proportion of water might be expected to separate, when the temperature fell to a certain point, into a lighter, upper layer consisting largely of water, the more acid constituents and the excess of silica, and a heavier, lower layer made up mainly of the basic constituents and with comparatively little water.

In this way the formation of the great differentiated sills such as those of Sudbury and the Transvaal, might be explained. It might be objected that in such cases there was usually a continuous, though rapid, passage from one rock to another, but that was only what might be expected if consolidation were preceded by the loss of most of the water, following which the two magmas would again become miscible with one another. One looked to experimental work, such as was being carried out by Dr. DAY and Dr. WRIGHT at Washington, to determine whether this supposition was well founded.

It was to be expected that the character of the differentiation would depend on the amount of water present. If this were large, one would expect a comparatively complete removal of the alkali-felspar materials from the basic constituents of the basic minerals, and a larger proportion of the more acid and alkaline constituents; and with further differentiation by other processes this would naturally give rise to a series of rocks of the alkali or "Atlantic" type. This suggestion—it was intended to be nothing more—appeared to derive some support from the frequent association of rocks of this character with block-faulting, while rocks of the normal or "Pacific" type were usually found within areas characterized by folding, where there was less facility for the escape of water to the surface.

L. V. PIRSSON (New Haven, U.S.A.), desired to emphasize the fact that the phenomena which we term differentiation present an extremely complex problem and that many of the most fundamental things upon which assumptions concerning it are based, are as yet unknown. He instanced that the water in magmas must be heated beyond the critical point and that as yet nothing to speak of was known about the capacity and action of this water as a solvent. Yet it was constantly assumed that it would dissolve and carry in solution a great variety of substances, and certain theories regarding the origin of rocks and ores were built upon this assumption. He thought that more information of a definite nature was needed before any positive general theories could be formulated.

G. F. BECKER (Washington), called attention to the fact that magmas probably never were homogeneous because of the slowness of the process of diffusion.

Mr. EVANS wished to add a word in explanation of his previous remarks. If anyone found difficulty in supposing that water above its critical point was capable of dissolving silicates, the difficulty might be removed by considering the molten silicates to have dissolved the gaseous water. The difference was unimportant; there was a homogeneous mixture of both at high temperature and pressure. Also it was impossible to doubt that if the pressure were sufficiently great there would be no distinction between a liquid and a gas. Under such conditions the critical point would cease to have any significance.

J. P. IDDINGS (Washington), said that it was not correct to say that all petrographers assumed a homogeneous earth and a homogeneous general magma as the source of local or regional magmas. The demands of astronomy and of the conception of isostasy necessitated a heterogeneous earth. However, the heterogeneity of igneous rock series was of a very different order of magnitude volumetrically, from that of the earth astronomically considered. The differentiated bodies of igneous rocks were of extremely small size compared with the volume of the earth.

Mr. IDDINGS also remarked that he would make no attempt to discuss the papers that had [illegible] presented at this session, but would register his disagreement with a number of hy[illegible]es that had been advanced.

[illegible] **DAHLBOM** (Falun, Sweden): When Professor LOEWINSON-LESSING spoke on primary and secondary crystallization, I was encouraged to speak on one question which seems to me to involve the same problem. I wish to draw attention to the fact that at high temperatures, liquids have greater coefficients of expansion. Water, for instance, expands ten times as much at 320°C. as at 50°C. One volume at 4°C. expands to two volumes at about 360°C. The critical temperature of water is, according to recent investigations, 374°C. (DAVIS, 1909; HOLBORN and BAUMANN, 1910). Its critical volume is, according to DAVIS, 3.04, or specific gravity 0.329.

The critical temperature of solutions is something quite different from the critical temperature of a pure substance. It has been asserted here that solubility at critical temperature is very slight. So it is, when the pressure is not higher than the vapour tension of the solution, but in the interior of the earth, or even at a depth of some hundred metres, the pressure is much greater than the critical pressure, and the same will be true regarding the solubility.

From all that is known about volcanic eruptions, it seems probably that a magma is a solution of silicates, as solute, in water, chlorides, fluorides, etc., as solvents.

If we could melt a mountain of igneous holocrystalline rock we would obtain molten rock, that is, molten silicates. If this were cooled very slowly, the same minerals as before would not result, because their formation temperatures are much below the temperature at which the molten rock solidifies. This may be shown by means of a simple experiment. Heat a piece of granite, for instance, for one or two hours at a temperature 200° below the melting-point of any of its minerals. A thin section cut from it will then show that the minerals of the granite have begun to corrode, to destroy each other along edges of contact. At a temperature 200° below the melting-point there is, therefore, a tendency to assimilation instead of differentiation.

The lowered temperature is caused by solvents, termed in mineralogical literature mineralizers. Oxide of tungsten, WO_3, with the molecular weight of 232, is a well-known mineralizer. Now physical chemists inform us that the power of lowering the melting-point decreases with increase of the molecular weight. The lowering power of water (molecular weight 18) ought therefore to be $\left(\frac{232 = 13}{18}\right)$ about 13 times as great as that of oxide of tungsten. *A lower melting-point will result in a magma from the presence of water and chlorides.*

The content of water, of low specific gravity, must, *in spite of the contraction* which always exists in concentrated solutions, have a tendency to lower the specific gravity of the magma below that of molten silicates or of the minerals precipitated from it. The minerals *heavier* than the magma *must sink into it*. In general it is supposed that heavy minerals do *not* sink and that they are formed *in situ*, but the opposite opinion is more probable.

If precipitated minerals sink very slowly in the magma and grow during the sinking, they will collect on the bottom as idiomorphic minerals. Later, when the solution surrounding them has differentiated, the allotriomorphic minerals representing the *secondary* crystallization will form.

The hypothesis that a magma freezes from the bottom upwards will also explain what Dr. DALY has said regarding the different composition of sills and laccoliths at different depths.

A. BERGEAT (Königsberg): Soweit bisher überhaupt Untersuchungen über die Reihenfolge verschiedenartiger Ergussgesteine in Vulkangebieten vorliegen, lässt sich erkennen, dass in dieser Beziehung eine strenge Gesetzmässigkeit nicht waltet. Insbesondere werden des öfteren Recurrenzen angegeben; die Möglichkeit scheint zu bestehen, dass es sich dann manchmal nicht um die Produkte desselben, sondern um Produkte verschiedener benachbarter Magmaherde handelt, die sich in einem verschieden weit vorgeschrittenen Zustand der Magmawandlung befinden. Im grossen und ganzen bestätigt sich die schon von VON RICHTHOFEN gegebene Regel, dass auf Pyroxenandesite die saureren Amphibol- und Glimmerandesite, und auf diese Rhyolith und Basalte, folgen.

Ein sehr schönes und einfaches Beispiel für die Veränderung der Effusivgesteine in einer vulkanischen Provinz bieten die äolischen Inseln. Die Eruptionen begannen dort mit massenhafter Förderung olivinreicher Feldspatbasalte mit etwa 50 Proz. SiO_2. Auf sie folgten zunächst Pyroxenandesite, dann Amphibol- und Glimmerandesite. Mit ihrer Förderung erschöpfte sich die eigentliche Vollkraft der vulkanischen Tätigkeit. Spätere Eruptionen förderten dann neben einander ganz basische basaltische und ganz saure Gesteine, wobei sich unter den ersteren leucitführende Typen einstellen. Die Produkte der äolischen Vulkane sind also zunächst pazifischer Art gewesen und hypersthenführende Andesite spielen unter ihnen eine grosse Rolle; späterhin führt die Wandlung des Magmas zum Erguss von Laven von atlantischem Charakter. Ich möchte das Auftreten der letzteren auf den äolischen Inseln für eine Art Senilitätserscheinung halten.

Sehr merkwürdig scheint mir folgendes zu sein. Wäre die Veränderung der Laven auf den äolischen Inseln eine Folge der Differentiation in einem *enger begrenzten* Herde, dann müsste man wohl erwarten, dass neben den basischen Spaltungsgesteinen in dem ungeheuer langen Zeitraum ihrer erstmaligen Herrschaft auch saure Laven auftreten; man findet aber solche neben den älteren Gesteinen der Liparen nie, sondern es vollzieht sich zunächst nur der vorher erwähnte Übergang von recht basischen Gesteinen zu solchen von mittlerem Kieselsäuregehalt.

N. L. BOWEN (Washington): A good deal has been said this afternoon concerning the critical point of water, and it has apparently been considered as a fixed point. As a matter of fact the critical point of water may be indefinitely raised by the presence of other substances which it may take into solution. This subject has been fully discussed by Dr. PAUL NIGGLI in recent papers in the Zeitschrift für Anorganische Chemie.

W. S. BAYLEY (Urbana, U.S.A.): It may prove a relief to this assembly if, before adjournment, some one rises for a minute to corroborate some statement made by some one of the preceding speakers. I am therefore glad to be able to say that I thoroughly agree with Dr. DALY in his statement concerning the origin of the "red rock" of Minnesota. Indeed, so thoroughly was I convinced of the syntectic origin of the "red rock" when studying the exposures on Pigeon Point, that, after completion of the report in this district, I began a study of all the occurrences of "red rock" in Minnesota, with the intention of testing the hypothesis that it had originated by solution of quartzites and slates in gabbro magmas, but the study was never completed. I am, however, not prepared to follow Dr. DALY in the inference that the solution of fragments has affected material changes in the composition of the dissolving magma. The Duluth gabbro is affected by the assimilation of fragments only for a short distance from its contact with the invaded rocks. If much "red rock" was made by the process, most of it was forced into the overlying beds.

H. BÆCKSTRŒM (Stockholm): I think we all agree with Professor Pirsson and Professor Daly that differentiation is a very complex process. In the quarter of a century that has elapsed since its principles first were introduced we have seen many fine examples of consanguinity, and nobody here to-day has denied that differentiation takes place on a large scale. But many aspects of the problem, for instance the mechanics of differentiation, we do not know.

It has been mentioned several times to-day that I tried twenty years ago to introduce liquation—a limited solubility of molten rock-minerals into each other—as one of the causes of differentiation. This was in a certain way only an extension of the "Kern-theorie" of Rosenbusch. Although I believe much may be said in favour of this hypothesis, it has as yet not been proved.

That fractional crystallization plays an important part seems certain, but this has hitherto not been followed up in detail.

Another question of importance as to the origin of igneous rocks that has been touched upon to-day is how far assimilation of surrounding rocks may have influenced the composition. Professor Hobbs considers certain igneous rocks to have originated through the melting of slates, but I do not see as much similarity between the analyses shown in the table and diagram as the author appears to find. His enthusiastic and earnest plea for the assimilation theory ought to receive due consideration but must be carefully tested by the field geologist as well as by the chemist.

In conclusion I join Dr. Washington in his hope that future experimental work may add to our knowledge of the phenomena of differentiation. I hope some future Chairman, in three or six years from now, will call upon Dr. Arthur L. Day to give us his opinion regarding these problems.

Sujet No. 3: L'influence de la profondeur sur la nature des gisements metallifères.

THE INFLUENCE OF DEPTH ON THE CHARACTER OF METALLIFEROUS DEPOSITS.

BY

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Modern improvements in the art of mining have made possible the sinking of shafts to greater and greater depths. The copper mines on Keweenaw Point, Lake Superior, have several which exceed 5,000 feet and a larger number between 3,000 and 4,000 feet. The deepest of these shafts attains the lowest point beneath the earth's surface yet reached by man himself, but as is generally known, the drill, although not in search of metals, has gone 1,500 or more feet deeper. We are thus learning by actual observations the mineralogical conditions at increasing depths and also the effect of depth upon values.

The questions thus raised have three sides, all of much interest. On the one side is the actual engineering problem of deep mining. Assuming that ore maintains values such as we customarily obtain to-day, we may raise the question, how deep is it feasible to sink for its extraction? Hoisting cables, when used in single lifts, have a limit beyond which their own weight makes them impracticable. Hoisting must therefore be performed in several steps, and power must be transmitted to some sort of engines at successive depths. Rock pressure upon excavations becomes very great, making the support of roof and walls increasingly serious. Water can, however, almost always be impounded in upper levels, so that pumping need not be a drawback, but in regions of recent vulcanism, such as the Comstock Lode, it may be an important factor in depth. Happily, well-nigh universal experience shows that water is practically limited to the upper one or two thousand feet of the earth's crust. Increasing temperature is, however, a great handicap on the miner. If, as in the deep mines of Keweenaw Point, men must work in confined drifts and stopes at the temperature of a hot summer day, only the exhaust of compressed air from the drills makes conditions favourable for effective labour. Some years ago, Dr. ALFRED C. LANE, at the time State Geologist of Michigan, the state which contains the very deep mines, discussed the question, "How deep can we mine?" and reached the conclusion that 10,000 feet, was the practicable limit.[1] Were, however, unusually rich ore to be had, a somewhat greater depth might be reached.

On another side the whole problem is affected by what we have learned with regard to the values of ore with increasing depth. Recorded experience

[1] ALFRED C. LANE, The Mineral Industry, Vol. IV, New York, 1895, pp. 767-80.

is multiplying, and at least two observers have summarized world-wide results in mining. To this topic we will return in a moment, after stating the third point of view, which is the purely scientific one of the effect of increasing depth upon those geological conditions which influence the precipitation of ores. In casting light upon this phase of the matter we have the results of some artificial experiments in producing minerals and in the behaviour of rocks under pressure which are of decided interest.

It is also important, in the preliminary way, to bear in mind the metal or metals in whose search our deepest shafts have been sunk, and to comment on the types of ore-body which they have developed. In the citations below a general summary of the deepest is given and to this one or two others may here be added. Copper in the native condition is the object of deep mining on Keweenaw Point and is a very unusual form of this metal. We would normally expect sulphides. The ore-bodies now sought are not in veins or deposits which fill old fault lines or crushed zones and their attendant waterways, but are impregnations of conglomerates and amygdaloids. There are, indeed, a few old mines based upon fault fissures but they have never been followed to depths beyond the ordinary. The precipitation of this vast quantity of a native metal which is found in the usual course of mining only in the gossan, presents an exceptional problem. The native copper has been followed nearly or quite a vertical mile below the level of the ground-water and obviously cannot be due to descending surface waters when the enclosing rock had any such attitude with regard to the surface as at present. These deep mines do not throw much light on the circumstances attending the ordinary precipitation of sulphides.

The other very deep mines, say below 4,000 feet, are not many and have chiefly been sunk for gold. Two shafts developed saddle reefs in Victoria, and one, doubtless soon to be the deepest of all, follows a vein at Morro Velho, in the State of Minas Geraes, Brazil. The deep shafts in Kolar district, India, seek gold-quartz. The deep shafts in the Transvaal have likewise been sunk for gold, but, of course, not upon ordinary fissure veins. The famous Adalbert shaft at Przibram sought silver and attendant base metals down to 3,600 feet. On the Comstock Lode silver and gold were the objects and the deepest shaft was 3,350 feet. Copper, with attendant silver has already been followed to 3,000 feet at Butte, Montana, in sulphides and sulph-arsenides. Silver-bearing galena in brecciated quartzites has been developed to 2,500 feet below the crest of the overlying ridge at Wardner, Idaho. Tin in cassiterite has been obtained at still greater depths in Cornwall. Yet in summary we must admit that the very deepest shafts of to-day have had native copper or gold-quartz as their objectives, and the deepest experience which is now available relates to these two metals. We do know, however, aside from such pyrite as may occur with native gold, of sulphide ores, from 2,500 to 3,600 feet below the present surface. In time additional data will undoubtedly be gained regarding others.

Returning to the second point enunciated above, there is no doubt that, in most cases, values in ores decrease in depth after a moderate section of the vertical extent of the vein has been passed. This experience is not universal but it is the rule. The subject is generally discussed in our larger textbooks on ore deposits, and to these and to several older papers, two important ones have been added in the last two years by engineers of wide experience.[1] If, therefore, the yield of veins or other forms of ore-bodies is considered at the extreme depths now reached in mining, say 3,000 to 5,000 feet, we must realize that general experience points to lessening values, and the commercial probabilities are discouraging for any new and unexplored property. The experience thus far gained, as noted above, chiefly relates to copper and the precious metals, and to gold much more than to silver.

Several considerations are, however, of interest. In all ore-bodies involving sulphides of copper; to a large degree in those containing gold in association with pyrite; and to an important degree in those involving sulphides of lead and zinc, the three zones in vertical order from above downward, viz., the oxidized zone, the zone of enrichment and the zone of sulphides, must be considered. They have led to important changes in the distribution of values. Even gold itself, when associated with pyrite and manganese, and not in the presence of calcite or dolomite, undergoes secondary enrichment, as W. H. EMMONS and F. T. EDDINGFIELD have recently and acutely shown.[2]

The oxidized zone does not extend below the permanent ground-water level. It is of no importance in connection with the questions before us, except

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[1] F. LYNWOOD GARRISON, *Decrease of value in ore-shoots with depth.* Trans. Can. Min. Institute, Vol. XV, 1912, pp. 192-209.

T. A. RICKARD, *Persistence of ore in depth.* Min. and Sci. Press, 1912, pp. 232-233, 261-267.

Mr. GARRISON mentions the following deep shafts: Victoria Reef Quartz mine, Bendigo, 4,000 feet; San Juan del Rey Gold Mining Co., Morro Velho, Brazil, nearly 5,000 feet vertical, or 7,000 feet on the incline; Tennants, Mysore, India, 2,790 feet; and several others of less depth. Mr. Garrison specially emphasizes the values found at these depths. In all these cited good values were still obtained at the depths mentioned but the Bendigo mines are stated by M. Rickard in the next citation to have been unprofitable at these great depths.

Mr. RICKARD adds the Adalbert shaft at Przibram, Bohemia, 3,600 feet, and then abandoned from decreasing values; two shafts on the Comstock Lode, respectively, 3,260 and 3,350 feet, stopped from decreasing ore and increasing hot water; several shafts in and near Calumet, Michigan, 5,253, 5,281 and 4,920 feet, all in lower grade copper rock than was met nearer the surface; Victoria Reef Quartz mine, Bendigo, Victoria, 4,614 feet, and New Chum Railway mine, 4,151 feet. Deeper sinking was abandoned in both mines from decreasing yield and increasing expense. The St. John del Rey Co., Morro Velho, Brazil, has an inclined shaft, 7,000 feet on the dip and 4,926 feet vertically. The company is still profitably operating on $11.00 per ton gold ore. As the shaft is still going down, some 300 feet more, vertically, will make it the deepest yet sunk. There are several shafts in the Kolar gold field of India, respectively 2,420, 2,751, 3,100 and 3,900 feet. Experience has shown that the ore is rich and poor in streaks. The Champion shaft at 3,900 feet was in ore as rich as any on the upper levels. On the whole Mr. Rickard's conclusions are emphatically in favour of the greater productiveness of the upper 1,000 to 2,000 feet than of the greater depths.

[2] W. H. EMMONS, Trans. Am. Inst. Min. Eng., Vol. XLII, pp. 3-73.

F. T. EDDINGFIELD, *Alteration and enrichment in calcite-quartz-manganese gold deposits in the Philippine Islands.* Philippine Journal of Science, Vol. VIII, pp. 125-131, 1913.

in very arid regions, where the ground-water lies unusually deep. Even then, however, the depths are not such as we are at present considering.

The extent of enrichment in depth is a matter of greater interest. It primarily depends upon the vertical depth to which we are prepared to admit that descending, acidified, metal-bearing solutions, produced by the leaching of the oxidized zone by meteoric waters, may slowly diffuse themselves in the standing ground-water. Obviously, the chief reactions will take place near the ground-water level. We cannot reasonably expect the influence to extend very far. The production of oxidized and enriched ores of zinc is practically limited to a few feet above and below the water level. Lead is very intractable and its enrichment is practically a matter of oxidization and removal of other and more soluble associates above the water level. The behaviour of silver is a matter on which we need light and on which there is a difference of opinion among engineers. Some have regarded the argentite of Mexican silver mines as the result of secondary enrichment and have inferred its disappearance at comparatively moderate depths. On the other hand, in the microscopic study of at least one suite of ores, from the State of Guerrero, in the endeavour to decide this point, since it affected exploration below a fault, the writer could find no evidence that the argentite was not one of the original vein minerals. Explorations subsequently undertaken seemed to justify this conclusion, as the vein, with ores unchanged, was found below the fault. Depths of 700–800 feet were involved. Silver becomes so readily locked up as the relatively insoluble chloride, cerargyrite, through the precipitating influence of ordinary surface waters, that it is not so favourable a metal for secondary enrichment as are several others. Gold, though at first sight a comparatively insoluble metal, does yield to the solutions afforded by oxidizing pyrite, in the presence of manganese, as was mentioned above. To what depth, however, the slow diffusion of descending solutions would bring the enriching effects below the water level is a question. Probably the range would not be great and the presumption is strong that the native gold found rarely in large nuggets at great depths in quartz veins is an original precipitate in the vein filling. For great depths, such as those in the Bendigo saddle reefs, it is impossible to refer decreasing yields to waning secondary enrichment.

Copper is the metal of pre-eminent importance in matters of secondary enrichment. Reported falling off in values as greater depths have been attained, has made the influence of this process of special importance. The appreciable decrease in copper percentages which were widely published fifteen years or so ago, regarding the Rio Tinto mines, called attention to it even at this early date. That enrichment may take place for several hundred feet below the permanent water level seems fairly well established both by the experience gained from the disseminated copper deposits ("porphyry coppers") of recent development, and by that gained in our deeper copper mines. In the disseminated copper mines experience shows that, from a condition of maximum enrichment, percentages gradually decline until, within a very moderate vertical range of a few hundred feet, we reach the original lean, copper-bearing and unchanged pyrite. In the great mines at Butte, of which we have descriptions from W. H. Weed,[1] and more recently from R. H. Sales,[2] the latter shows that the demonstrable, secondary chalcocite only extends a short distance below the water level, say two or three hundred feet, although the distance of the water level from the surface is remarkably variable in the different mines. So far as the original vein-filling is concerned, there seem to be no identifiable mineralogical differences in vertical range, so far as we have yet gone, down to 3,000 feet. There is, however, a marked change as we radiate horizontally outward from a central area of copper minerals with no manganese and little or no zincblende, through a zone with decreasing copper and increasing zinc and manganese, to a zone with little or no copper and with silver in association with zincblende, a little galena and great quantities of rhodonite and rhodochrosite.

If, therefore, when we consider behaviour with depth, we focus attention upon the same minerals, at the most, lessening in quantity, or much the same minerals with lessening content of the precious metals, in mass a very small part of the veins, we would naturally seek the influence of physical conditions to account for less abundant or less profitable ore.

One other consideration should be first mentioned before briefly referring to the physical conditions. Vein formation in our workable deposits has usually taken place from one to several geological periods ago. Erosion has been active since and has removed an appreciable section of the rocks which existed when the deposition took place. In very ancient veins, such as appear in Pre-Cambrian strata, the lost section may be important. Mr. Garrison has laid especial stress upon this phase of the subject, and has remarked Mr. Lindgren's inference that the lowest explored Bendigo saddle reef had formed when at least 7,000 feet from the surface; that the ores of the Mother Lode, California, had been precipitated at 6,000 feet; that the gold-bearing veins of the southern Appalachians must have been deposited over a vertical range of 7,000–8,000 feet; and the conclusion of Mr. F. L. Ransome that erosion has removed 2,000–5,000 feet of rock from Cripple Creek, Colorado. We may add that Dr. S. F. Emmons stated his belief, in his famous monograph on Leadville, Colorado, that the ores had been precipitated when 10,000 feet below the surface. Many other cases could be easily cited, but these will suffice to make clear that even the ores which we mine to-day, and which have been unaffected by secondary enrichment, were originally precipitated at much greater depths than the present workings. The physical conditions involved in vertical depth, down to 6,000–10,000 feet, would not seem to be of themselves prohibitive of the precipitation of commercial ore.

Still another feature of veins is the distribution of ore in shoots, with barren stretches between. Shoots succeed one another both in vertical and in horizontal distribution. Exploration is much more expensive at great

[1] Professional Paper, No. 74, U.S. Geol. Survey.

[2] Mr. Sales' paper will appear in the August, 1913, Bulletin of the American Institute of Mining Engineers, and includes the developments of the last six or seven years, which are not included in Mr. Weed's paper.

depths than nearer the surface, and under these circumstances operators may much more easily become discouraged in the search for new veins when old ones become exhausted. We can hardly say that ore does not persist, even though it may not be commercially profitable to sink or drift for it.

The matter of possible cavities deserves a word of comment. While, as has been so ably shown by the honoured President of this Congress, Dr. FRANK D. ADAMS, cavities are still possible at depths of 10 or 12 miles, yet large open spaces such as would form a resting place for ores, aside from replacement, would be naturally best developed within moderate distances from the surface. Mr. RICKARD has commented upon this feature of the subject, and doubtless it is one of the serious factors influencing the final result.

As time passes, students of these phenomena seem to be increasingly convinced that the veins, such as would be considered in connection with profound depths, have been filled by uprising heated solutions. Since high temperatures generally favour solution and heavy pressures cannot be without their influence as well, decreasing temperatures promote precipitation with increasing efficiency as the surface is approached. Undoubtedly in these influences we have an explanation deserving confidence. There may well be a vertical range, wherein precipitating influences are at their best,—one which corresponds with the section marked by our profitable ore bodies in the mines. The slow erosion of the tops of veins, with the attendant sinking of the ground-water level, serves further to enhance values by the processes of enrichment. Ore-bodies of metals, other than iron, which have been precipitated at or immediately below the surface by uprising heated waters are extremely rare. Sulphur Bank, California, and Steamboat Springs, near Virginia City, Nevada, with their relatively small yields of quicksilver, are almost the only ones which suggest themselves. Mr. LINDGREN has also remarked that ore-bodies in purely surface flows of eruptive rocks are relatively rare. Ore-bodies are much commoner in association with intrusive rocks or with others which have been deeply buried.

We are now pretty well assured both from the study of mineral springs and from the artificial production of some of the minerals common in ores, that the uprising solutions are alkaline in character. Only in the descending meteoric waters which leach the outcrops, do we find acid solutions. The deep-seated waters are carbonated and often charged with hydrogen sulphide. The descending waters are oxygenated. The most common and widespread sulphide in veins in general, is pyrite, and it has special claims to interest because of its parallel mineral, marcasite. Messrs. ALLEN, CRENSHAW and JOHNSTON of the Carnegie Geophysical Laboratory in Washington have recently made some experiments in the production of these two which are of extreme interest.[1] On p. 171 of their paper is the following passage: "The pyrite of deep veins, metamorphic contacts and hot-springs, as well as magmas, has been formed by hot solutions, and such solutions never contain

[1] E. T. ALLEN, J. L. CRENSHAW and JOHN JOHNSTON, *The mineral sulphides of iron*. Amer. Jour. Sci., March, 1912, pp. 169-236.

strong mineral acids, but are generally, if not always, alkaline. The pyrite and marcasite of surface veins, on the other hand, are formed from cold solutions, which often contain considerable sulphuric acid." In their experimental production of pyrite, hydrogen sulphide was the quite invariable precipitant; the reduction of sulphates seems to be an assumption, not corroborated by experiment. With the reagents employed, pyrite formed very slowly at room temperatures, but much more rapidly at 200° C. On p. 192 the following passage appears: "Pyrite, being a stable form, probably crystallizes under a considerably wider range of conditions than marcasite. The evidence of synthetic study is that the formation of pyrite is favoured by high temperatures and by solutions which contain little or no free acid. In accord with these we have the following geological deductions. First, pyrite is the product of hot-springs. In the springs of Carlsbad which have a temperature of 55° C, recent pyrite is observed. The waters contain sulphates and a trace of hydrogen sulphide and are slightly alkaline. The lagoons of Tuscany are depositing pyrite from their hot waters. Bunsen found that the hot vapours of the fumaroles of Iceland were gradually changing the ferrous silicate of the basalts into pyrite. More important geologically is the fact that the product of deep veins by ascending waters is always pyrite, never marcasite. Such waters are naturally hot, and commonly, if not always, alkaline. We can now see that the separation of pyrite from a magma is entirely possible, while the temperature of any magma would doubtless be incompatible with the existence of marcasite."

As bearing on the problem of the continuation of ore in depth we can only conclude from the experiments and observations of Messrs. Allen, Crenshaw and Johnston that pyrite *can* precipitate at a depth fully as great as any shaft yet sunk.

Very similar conclusions have been established by Messrs. CRENSHAW and ALLEN for the two sets of parallel minerals sphalerite and wurtzite and cinnabar and metacinnabar.[1] On p. 396 of the citation they summarize their conclusions as follows: "Comparing the genetic relations of the minerals sphalerite and wurtzite, cinnabar and metacinnabar, with the genetic relations of pyrite and marcasite, we find certain remarkable regularities. The *stable forms* sphalerites, cinnabar and pyrite, are always obtained by crystallization from alkaline solutions (solutions of the alakali sulphides), while the *unstable forms* wurtzite, metacinnabar and marcasite, are obtained from acid solutions only. The stable forms may also be crystallized from acid under certain conditions. Of these, temperature and acid concentration seem to be the important ones.

Certainly with pyrite and marcasite, and in all probability with sphalerite and wurtzite, the higher the temperature the greater the percentage of the stable form obtained, while the higher the acid concentration at any temperature, the greater is the percentage of the unstable form obtained. These

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[1] E. T. ALLEN and J. L. CRENSHAW. *The sulphides of zinc, cadmium and mercury, their crystalline forms and genetic conditions;* Amer. Jour. Sci., Oct., 1912, pp. 341-396.

facts appear to agree remarkably well with the field evidence, which relates to the genesis of the natural minerals, while they give new significance to the general geologic distinction between deep-seated and surface waters in nature."

The experiments of these investigators clear up for us the fundamental chemical differences between the processes of primary precipitation and of secondary enrichment, but as regards the continuation of ore in depth, we can only say:

1. While there seems to be nothing to prevent precipitation at greater depths than we have yet reached, yet conditions seem to be specially favourable in those portions which lie between the present surface and 2,000–4,000 feet in depth.

2. Secondary enrichment has increased the yield of those portions of many veins which are above 1,000 feet in depth, the vertical extent of its action being limited to a relatively short stretch below the ground-water level.

THE MINERAL COMPOSITION OF PRIMARY ORE AS A FACTOR DETERMINING THE VERTICAL RANGE OF METALS DEPOSITED BY SECONDARY PROCESSES.[1]

BY

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INTRODUCTION.

The theory of sulphide enrichment announced independently in 1900 by S. F. Emmons,[2] W. H. Weed,[3] and C. R. Van Hise,[4] has been successfully utilized in the exploration of so many mineral deposits that it has become an accepted tenet of applied geology. The processes involved are assumed to include, (1) solution of the valuable metals in an oxidizing acid environment in advance of the removal by erosion of the outcrop of the ore body; (2) transportation by descending meteoric waters of the metals dissolved; and (3) precipitation of the valuable metals in depth where the environment is reducing and perhaps alkaline.

Although our knowledge concerning the details of the chemistry of the processes is inadequate, the general nature of these chemical processes is fairly well understood. Few geological processes lend themselves more readily to experimental study. The mineral waters, as shown by study and comparison of numerous analyses of mine waters, may reasonably be assumed to be dilute solutions of sulphates and chlorides. The conditions of temperature and pressure which prevail are not very different from those obtaining in the laboratory. Hence the behaviour of the various minerals and ores in the presence of solutions like mine waters may easily be determined. By close correlation of field observations and laboratory experiments, it appears probable that in the near future we will know many of the details of the processes as well as we now know the nature of the general laws that operate in the weathering of a body of sulphide ore.

These processes are influenced by many factors. Among those of environment are temperature, rainfall, altitude, and relief. An important

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[1] Published with the permission of the Director, United States Geological Survey.

[2] *The secondary enrichment of ore deposits;* Trans. Am. Inst. Min. Eng., Vol. XXX, 1901, pp. 177-217.

[3] *The enrichment of gold and silver veins;* Trans. Am. Inst. Min. Eng., Vol. XXX, 1901, pp. 424-448.

[4] *Some principles controlling the deposition of ores;* Trans. Am. Inst. Min. Eng., Vol. XXX, 1901, pp. 27-177.

physical factor is the permeability of the deposits. And so many geological events may affect, in one way or another, the operation of the processes of enrichment that the use of the theory is fraught with danger unless it is applied with an adequate knowledge of the geology of the region containing the deposits.

A review of the distribution of sulphide deposits having secondary zones shows that they are present at high and low latitudes, at high and low altitudes, in moist and in dry climates. They are present also in hot and in cold countries, although they are less numerous in high latitudes, especially in countries where Pleistocene glaciation has removed much of the surface.[1]

On the other hand, many mining regions contain deposits with rich secondary zones, while other sulphide deposits that have weathered in the same region and under similar physiographic conditions, exhibit no evidence of appreciable enrichment. In general, such differences in the behaviour of deposits, under approximately similar conditions have been attributed to differences in their permeability; and very correctly so, for in impermeable deposits the solutions cannot descend, and the valuable metals that may be dissolved in the upper portions of a deposit cannot be precipitated in the impermeable lower regions. Permeability is, however, a relative term and it is doubtful whether any deposits are altogether impermeable.

Another factor that influences the depth at which metals may be deposited is the chemical and mineralogical environment. If the conditions in the oxidizing zone are favourable to solution, the metals will be dissolved; if they are unfavourable to solution the metals will remain to enrich the outcrop or to be carried away by processes of erosion. If the chemical environment in the lower unoxidized regions is favourable to rapid precipitation, the valuable metals will be precipitated before the downward moving solutions have migrated to great depths. The secondary zone may contain very rich ore, but the vertical extent of the latter will be less in consequence. On the other hand, if the minerals that compose the primary ore are those that react but slowly with the downward moving secondary solutions, precipitation of the metals will not be accomplished so readily, and the metals dissolved in the higher oxidizing environment may be carried downward to considerable depths. In deposits composed of such minerals the vertical extent of the secondary ores will be much greater than in deposits containing minerals that quickly precipitate the valuable metals.

If the behaviour of solutions like mine waters containing gold, silver, and copper in low concentration, toward each of the minerals of an ore and toward mineral associations were known, from experiment, and if the permeability of the deposit were ascertained, some estimate might be hazarded, perhaps in advance of extensive exploration, as to whether the secondary ores of a deposit would extend downward to considerable depths or whether they would be restricted vertically.

[1] WINCHELL, H. V., *Prospecting in the North*, Min. Mag., Vol. III, 1910, pp. 436-438, BROCK, R. W., *Discussion of H. V. Winchell's article, "Prospecting in the North,"* Min. Mag., Vol. IV, 1911, pp. 204-205.

Examination and study of about fifty analyses of waters of gold, silver, and copper mines indicate that mine waters are fairly constant in composition. Near the surface they are acid sulphate and ferric sulphate waters. At greater depths they are acid ferrous sulphate waters, and deeper still they become alkaline ferrous sulphate waters. If the behaviour of such waters toward a given ore were known, and if the rate at which the solutions, under the several conditions of acidity and alkalinity, attack the primary ore were determined by experiment, much light might be thrown upon the superficial processes and upon the rate at which they operate under a known set of conditions.

EXPERIMENTAL DATA.

The experimental data relating to this problem, though altogether inadequate, are rapidly increasing. Many records of experiments showing the effects of various solutions on various minerals are available, but not many series of experiments designed to show differences in the behaviour of solutions like mine waters toward different minerals, and very few indeed that show the effects of such solutions on associations of ores. The first series of experiments of this nature, I believe, was made by VOGT.[1] He treated chalcocite, bornite, pyrrhotite, chalcopyrite, and pyrite separately with a strong solution of ferric chloride and found that the minerals were dissolved in the order named. Since the solution was oxidizing, this might be assumed to represent the order in which these minerals are dissolved in nature in an oxidizing environment. In connection with studies of enrichment of ores that occur at Ducktown, Tennessee, DR. R. C. WELLS undertook a series of experiments designed to show the rate at which a dilute acid sulphate solution is reduced by several minerals that are present in the Ducktown ores. He measured the rate at which hydrogen sulphide is generated, and since hydrogen sulphide precipitates gold, silver and copper at the same time from acid solutions, his series may be assumed to represent the rate at which the minerals in question react on downward moving sulphate waters and precipitate these metals. In his experiments five minerals were further exposed overnight to 0.057 normal sulphuric acid The resulting solutions were titrated with iodine solution to ascertain amount of hydrogen sulphide generated, the amount of iodine solution being, for pyrrhotite, 28.5 cubic centimetres; for sphalerite, 1.05 cubic centimetres; for galena, 0.40 cubic centimetres; for chalcopyrite, 0.29 cubic centimetres; for pyrite, 0.28 cubic centimetres.

In another series of experiments the hydrogen sulphide generated by the action of cold dilute acid on pyrrhotite, on sphalerite, and on galena was determined qualitatively with lead acetate paper. There was no evidence that hydrogen sulphide was formed with either pyrite or chalcopyrite, and the very small quantities indicated above (0.28 cubic centimetre and 0.29 cubic centimetre for chalcopyrite) are not regarded by Mr. Wells as proof that hydrogen sulphide is formed by the action of acid on pyrite and chal-

[1] *Problems in the geology of ore deposits*; in FRANZ POSEPNY, *The genesis of ore deposits*, 1902, pp. 676-677.

copyrite. The slight reduction of the iodine solution may represent a correction for the end point of the titration.[1]

Recent experiments designed to show the rate at which various minerals react on dilute sulphate and chloride solutions carrying gold, silver, and copper, have been made by H. C. Cooke,[2] Palmer and Bastin,[3] A. D. Brokaw,[4] and F. F. Grout.[5] These experiments afford a much better basis for the discussion of problems relating to the downward migration of metals than any heretofore available, since several minerals under similar conditions have been treated by the same solutions, thus giving opportunities for comparison.

Gold.

Gold, silver and copper are nearly related chemically and stand apart as metals in the concentration of which the processes of sulphide enrichment are most clearly expressed. They are dissolved in an oxidizing sulphate or chloride environment and are readily precipitated in a reducing, less acid, environment. Any one of them is readily precipitated by calcite, siderite, pyrrhotite, and probably by several other sulphides. Under conditions that prevail in the oxidizing zones of ore deposits, gold is dissolved probably only in the presence of a chloride and an oxidizing agent.[6] The most important oxidizing agents in gold enrichment are doubtless manganese oxides, for these not only supply nascent chlorine by reaction with chlorides in solution, but inhibit the accumulation of ferrous sulphate that immediately precipitates gold from chloride solutions.[7] In the deeper regions where oxides are reduced or acids are removed to form inert salts, gold is precipitated. Ferrous sulphate is doubtless an important precipitating agent,[8] but many common ore and gangue minerals are also effective. As stated by Brokaw,[9] the list includes many native metals, sulphides, sulph-arsenides, sulph-antimonides, etc. Of the gangue minerals calcite siderite, and some other carbonates throw down gold at once. Even comparatively stable minerals, like the feldspars and micas, give a distinctly alkaline reaction,[10] and, given time enough, an auriferous sulphate and chloride solution would be neutralized

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[1] Emmons, W. H., *The enrichment of sulphide ores*, Bull. U.S. Geol. Survey No. 529, 1913, pp. 59-60.

[2] *The secondary enrichment of silver ores*, Jour. Geol., Vol. XXI, p. 1, 1913.

[3] *Metallic minerals as precipitants of gold and silver*, Econ. Geol., Vol. VIII, 1913, p. 140.

[4] *The secondary precipitation of gold in ore bodies*, Jour. Geol., Vol. XXI, 1913, p. 251.

[5] In Press.

[6] Emmons, W. H., *The agency of manganese in the superficial alteration and secondary enrichment of gold deposits in the United States*, Bull. Am. Inst. Min. Eng., 1910, pp. 789-791.

[7] Brokaw, A. D. *The solution of gold in the surface alterations of ore bodies*, Jour. Geol., Vol. XVIII, 1910, p. 322.

[8] Emmons, W. H., Op. cit., p. 792.

[9] Jour. Geol., Vol. XXI, 1913, p. 252.

[10] Clarke, F. W., Bull. U.S. Geol. Survey No. 167, 1900, p. 156; Steiger, George, Bull. U.S. Geol. Survey No. 167, 1900, p. 159; Clarke, F. W., Bull. U.S. Geol. Survey No. 491, 1912, p. 456

and gold would be precipitated by many minerals of the gangue and of the wall rock.

Thus secondary gold ores might form in any deposit where conditions are favourable to solution of gold, but in a deposit composed of minerals that precipitate gold quickly, any gold dissolved would not be carried to great depths and the secondary ores would remain at least temporarily near the surface. One would not suppose that gold deposits containing much pyrrhotite or calcite or siderite would have as deep secondary zones as deposits containing only pyrite, quartz, feldspar, mica, and other minerals that react but slowly with the solutions.

Silver.

Like copper, silver dissolves readily in dilute sulphuric acid, and silver sulphate is dissolved by sulphuric acid if a little ferric sulphate is present.[1] Unlike gold, the solution of silver does not require the presence of a chloride, and unlike copper silver forms stable chlorides in the oxidized zone. If the descending mineral waters carry much chloride, silver tends to accumulate as cerargyrite, but silver chloride is itself somewhat soluble in water and more soluble in concentrated solutions of alkaline chlorides. Thus silver, even in deposits where the chlorides form, may be carried downward in solution and be precipitated at depths where conditions are reducing. Acid sulphate, reacting on pyrrhotite and some other minerals, as shown by Wells, will generate hydrogen sulphide, and hydrogen sulphide precipitates silver sulphides even from highly dilute solutions. Silver is precipitated also from sulphate solutions by stibnite, realgar, and orpiment.[2]

Solutions of ferric sulphide reacting with hydrogen sulphide[3] give powdery sulphur, and as shown by COOKE,[4] amorphous sulphur unites with silver sulphate to form silver sulphide, probably argentite.

The downward migration of silver in sulphide deposits is delayed not only by formation of the chloride, but also by precipitation of the native metal. Some recent experiments by PALMER and BASTIN[5] have a bearing here. Several minerals treated with silver sulphate precipitated native silver. The reaction was rapid with chalcocite, covellite, enargite, bornite, and tennantitite; less rapid with smaltite, pyrrhotite, chalcopyrite, and arsenopyrite; and weak or inactive with stibnite, pyrite, galena, millerite, and sphalerite.

MR. F. F. GROUT has shown that these relations will hold approximately where the solutions have acid in excess, and that carbonates,—calcite,

[1] COOKE, H. C., *The secondary enrichment of silver ores*, Jour. Geol., Vol. XXI, January, 1913, p. 12.

[2] Op. cit., p. 21.

[3] ALLEN, E. T., *Sulphides of iron and their genesis*, Min. and Sci. Press, Vol. CIII, 1911, p. 411. ALLEN, E. T., CRENSHAW, J. L., and JOHNSTON, JOHN, *The mineral sulphides of iron*, Am Jour. Sci., 4th ser., Vol. XXXIII, 1912, p. 169.

[4] Op. cit., p. 25.

[5] *Metallic minerals as precipitants of silver and gold*, Econ. Geol., Vol. VIII, 1913, p. 153.

siderite, rhodochrosite, and several others—precipitate silver rapidly after the acid is used up.

The precipitation of native silver in sideritic ores has recently been emphasized in a paper by EARL V. SHANNON[1] on the Caledonia mine of Cœur d'Alêne.

In deposits of ores of silver that contain abundance of the minerals that readily form the native metal in the presence of silver sulphate, one would suppose that the zone of secondary native silver would be rich, but that it would not have such great vertical extent as in deposits composed only of quartz, pyrite, and other less active minerals. Even in deposits composed of relatively inert minerals, precipitation of silver would take place ultimately if the deposits were sufficientl, permeable to permit a downward migration of solutions. Silver would be precipitated even on feldspars or other minerals of the wall rock, for, as SULLIVAN has shown, this reaction take place with surprising rapidity.[2]

But the migration of silver is not permanently delayed by precipitation in the form of halides and native metal, for, dissolving again in ferric sulphate solutions, it passes downward to form argentite and the complex antimony and arsenic sulphides. In many deposits, as in the Comstock Lode and at Tonopah, Nevada, these are the most important minerals. But little is known concerning the chemistry of their genesis. It is known, however, that many deposits of secondary silver sulphides are bottomed by sphaleritic ores, the zone of transition from rich to poor ore being at many places comparatively narrow. In view of Wells' experiments showing that sphalerite reacts readily with dilute acid to yield hydrogen sulphide, one might suppose that the decomposition of sphalerite had released compounds that were effective in precipitating silver. On the other hand, some sphaleritic deposits have relatively deep secondary zones.

In some districts, as at Cobalt, native silver is abundant. In others, as in the Comstock Lode and Tonopah, Nevada, it is rare. In the last named, and probably in all three, silver has been carried downward to be precipitated as silver sulphide and complex salts of antimony and arsenic.

Some recent work by MR. F. F. GROUT indicates that these salts are probably precipitated in an alkaline environment. He treated numerous sulphides with dilute alkaline solution and when the extract that was formed was added to dilute acid, silver and copper sulphate solutions, silver sulphide was precipitated. When antimony and arsenic were in solution complex mixtures of sulphides of these metals were obtained. The descending acid waters encroaching on an alkaline environment, where alkaline sulphides accumulate, will form in depth silver sulphides and complex silver salts instead of the native metal. The bottom of the zone of native silver does not indicate, therefore, the lower level of the zone of superficial alteration.

[1] Econ. Geol., Vol. VIII, 1913. In press.

[2] The interaction between minerals and water solutions, with special reference to geologic phenomena, Bull. U.S. Geol. Survey No. 312, 1907, pp. 37-64.

Copper.

Like gold and silver, copper is dissolved in acid sulphate and chloride solutions, in an oxidizing environment. Unlike gold, the presence of chlorine is not necessary for its solution, and unlike silver, it is rarely precipitated as chloride in the oxidizing zone. The native metal and its oxides, silicates, carbonates and sulphates may form directly from solution, but much of the rich oxidized copper ore composed of these minerals has doubtless resulted from the oxidation of a relatively rich sulphide ore that by processes of erosion has been exposed to oxidizing conditions. In ores containing abundant calcite, as pointed out by BARD,[1] there is a strong tendency to delay the downward migration of copper by the formation of relatively insoluble copper carbonates in the upper regions.

The secondary sulphide zones in copper deposits are more clearly expressed than in deposits of precious metals. This, I believe, is because the copper sulphides dissolve in acid sulphate very readily in an oxidizing environment, but are highly insoluble in acid in the absence of oxygen. In many districts, pyrite, pyrrhotite, sphalerite, or galena have been replaced by chalcocite. Acid waters reacting on some of these minerals liberate hydrogen sulphide, and since copper sulphide has an exceedingly low solubility, hydrogen sulphide will precipitate copper from dilute solutions. It is not certain that hydrogen sulphide is an intermediate product where the primary sulphides are replaced by copper, yet it is believed that the rate at which those minerals are attacked affords a kind of index to the rate at which they will reduce a copper sulphate solution. If so, pyrrhotite which yields hydrogen sulphide more rapidly than pyrite and chalcopyrite in acid solution, should bring about the precipitation of copper more readily that pyrite and chalcopyrite. The same relation holds also in alkaline waters, for pyrrhotite treated with alkaline carbonate, alkaline silicate, etc., yields alkaline sulphides much more rapidly than pyrite or chalcopyrite. Thus, in ore containing abundant pyrrhotite, the secondary sulphide zone, although it might be richer, would not extend to such great depths as it does in ores composed of pyrite and chalcopyrite and little or no pyrrhotite.

Zinc blende reacts with acid sulphate solutions more rapidly than pyrite and chalcopyrite, but less rapidly than pyrrhotite, and one would suppose that sphaleritic ores without pyrrhotite would be enriched to greater depths than ores in which pyrrhotite predominates, but quantittative data are not now available for discussion of the problem.

CONCLUSIONS.

In the pages above I have outlined some of the more important chemical relations that are involved in the processes of enrichment of sulphide ores of gold, silver, and copper, and have reviewed some of the more important experiments that may illustrate these processes. Conditions in nature are

[1] *Absence of secondary copper sulphide enrichment in calcite gangues*, Econ. Geology, Vol. V, 1910, p. 59.

so complex and so varied that the application of the results of laboratory experiments, especially where the latter are inadequate, is a hazardous undertaking. These problems have an important economic significance and incorrect conlusions, if given wide publicity, may retard commercial enterprise. Therefore, in drawing conclusions regarding the depths at which secondary ores may be expected to extend, one assumes a serious responsibility. I wish chiefly to show that here is a field for chemical research likely to prove exceedingly productive of results that will have an important bearing.

Nearly all of the recorded experiments have been made with free access of air, yet it is certain that the precipitation of the secondary sulphides takes place mainly in the regions where atmospheric oxygen is excluded. In very few of the experiments has the time element been adequately considered. In some instances the same mineral species has given widely varying results when treated with the same solutions under conditions that appear to be similar. The experiments in the laboratory are of great value, however, since they suggest working hypotheses that may be tried out in the field, and that may be tested for regions that are adequately described in the literature.

Attempting to test some of the hypotheses outlined above, I have scanned the literature of about one hundred mining districts yielding gold, silver, and copper, most of which are located in North America, and most of these districts are reviewed in the papers mentioned below.[1]

This data indicates that, for the deposits described, important secondary concentration of gold is probably confined to regions where waters carry chlorides and to deposits that contain manganese; that secondary gold ores in deposits containing much pyrrhotite or abundant calcite or siderite are probably of more limited vertical extent than in pyritic ores without pyrrhotite or carbonate; that many auriferous gold deposits with a carbonate gangue may supply placer gold and that such deposits are likely to have relatively rich outcrops. A manganiferous gold ore containing only those minerals that react slowly with gold-bearing acid sulphate and chloride solutions may show some enrichment of gold at moderately great depths.

Concerning the deposition of secondary silver ore, the results of laboratory experiments are not altogether in harmony. WELLS showed that sphalerite with acid sulphate yields an appreciable amount of hydrogen sulphide, which precipitates silver from exceedingly dilute solutions. PALMER and BASTIN, however, place sphalerite with the weak or inactive minerals since, after thirteen days' contact with silver sulphate in neutral solution, no silver was precipitated. GROUT treated a number of specimens of sphalerite with acid solutions of silver sulphate and found that those containing iron precipitated silver from sulphate solutions very readily, while those free from iron showed little or no precipitation. After treating with alkalies, however,

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[1] *The enrichment of sulphide ores*, Bull. U.S. Geol. Survey No. 529, 1913, pp. 162-252.

EMMONS, W. H., *The agency of manganese in the superficial alteration and secondary enrichment of gold deposits in the United States*, Bull. Am. Inst. Min. Eng., 1910, pp. 789-791.

sphalerite gave a precipitate of silver with acid silver solutions. Although there are many examples if rich secondary silver ores that are bottomed in low grade zinc-bearing ores, the influence of sphalerite in limiting the downward migration of silver is a problem that is only in process of solution. Calcite, siderite, and rhodochrosite, by precipitating native metal, delay the downward migration of silver. In many deposits this delay seems to have been only temporary, however. Rich silver ores in limestone have been found at considerable depths at Tintic, Utah; Eureka, Nevada; and in other districts. These carbonates are highly soluble in acids and they may readily be removed from the main channels in deposits that carry much iron sulphide. Abundant pyrrhotite would probably halt the downward migration of silver very effectively, but in the United States there are few if any important pyrrhotitic deposits that carry much silver. A few cents to the ton is present in the primary ores of Ducktown, Tennessee, and according to GENTH some of the ores of the secondary "black-copper floors" there carried more than .5 per cent. of silver. It is reported that the precious metals were concentrated with copper ores at depths of 50 or 60 feet below the surface in pyrrhotitic copper ores at Santiago, Cuba, but of this I have no exact data. There are many examples of shallow secondary chalcocite zones among the deposits reviewed. Nearly all if not all of those that are well defined are in pyrrhotitic ore deposits. The deepest secondary chalcocite zones are in ore bodies that contain little or no pyrrhotite.[1]

[1] EMMONS, W. H., Bull. 529, U.S. Geol. Survey, p. 165.

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ON THE FORMATION IN DEPTH OF OXIDIZED ORES AND OF SECONDARY LIMESTONES.[1]

BY

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Amongst the subjects selected for special discussion at this meeting of the International Geological Congress is the influence of depth on the character of metalliferous deposits.

It seems desirable to contribute to this discussion a principle that has been found useful when studying the genesis of a section of the manganese ore deposits of India. This principle indicates the possibility of formation of oxidized ore deposits at great depths. It is also of considerable use in explaining the origin of certain Indian crystalline limestones or marbles.

When deposits consisting of chemical sediments, such as oxides and carbonates, as of iron, manganese, or calcium, admixed with mechanical sediments, such as sand and clay, are buried in the course of time to a depth sufficient to bring them into the zone of anamorphism, a reaction takes place between the oxide or carbonate and the admixed siliceous material, with the formation of silicates, sometimes of simple but often of very complex composition, e.g., grünerite, rhodonite, various garnets, and many of the minerals found in impure crystalline limestones. The reactions involved frequently necessitate the elimination from the oxides of oxygen in excess of protoxide proportions, as from Fe_2O_3 and MnO_2; of carbon dioxide from carbonates; and of water from hydrated oxides, such as limonite.

It seems to be tacitly assumed that the oxygen, carbon dioxide and water thus liberated are removed from the scene of action. But it is conceivable that the pressure inducing the metamorphism may be so applied that these products are unable to escape. What will then happen when, in the course of time, this pressure is released? These gaseous or liquid substances—their physical state depending, of course, on the temperature and pressure—will probably effect a reversal of the original change, and this reversal will be the more rapid and complete the higher the temperature, and the sooner the release of pressure occurs after its incidence. For, if the pressure be very slowly released during the course of ages, it is probable that a portion of the elusive oxygen and carbon dioxide may escape, so that the reversal of the original reactions cannot be carried to completion.

I have applied this idea in a memoir on the manganese ore deposits of

[1] Published with the permission of the Director of the Geological Survey of India.

India,[1] to explain certain features of the manganese ore deposits of the Central provinces of India, which are associated with a series of rocks named the *gondite series*.[2] At the same time it explains satisfactorily the genetic relationship of certain crystalline limestones in the same area to pyroxenic gneisses, and their derivation, at least in part, from these gneisses.[3]

The *gondite series* is regarded as the product[4] of the metamorphism of a series of sediments composed of varying proportions of chemically deposited oxides and mechanically deposited sands and clays. The typical rock of this series is *gondite*,[5] consisting of a mixture of garnet (spessartite) and quartz, of which the spessartite is supposed to have been formed in accordance with the following equation:[6]

$$\underset{\text{Kaolin or clay}}{2\,H_2O.Al_2O_3.2\,SiO_2}+3\,(MnO_2.H_2O)+\underset{\text{Quartz}}{SiO_2}=\underset{\text{Spessartite}}{3\,MnO.Al_2O_3.3\,SiO_2}+3O+5\,H_2O.$$

Rhodonite was formed as follows:

$$MnO_2.H_2O+\underset{\text{Quartz}}{SiO_2}=\underset{\text{Rhodonite}}{MnSiO_3}+H_2O+O.$$

and in cases where the quantity of mechanical sediment admixed with the manganese oxides was small, braunite (primary ore) was formed according to the following reaction:

$$7\,(MnO_2.H_2O)+SiO_2=\underset{\text{Braunite}}{3\,Mn_2O_3.MnSiO_3}+4O+7\,H_2O.$$

Thus, as a result of the original series of metamorphic processes, the manganiferous sediments have been converted into a banded series of rocks, in which the chief minerals are spessartite, rhodonite, braunite, and quartz. Many other minerals occur, but they are comparatively unimportant.

Both field and microscopic study prove conclusively that a large proportion of the manganese ores associated with the rocks of the gondite series is not primary, however, but has been formed by secondary chemical alteration of the silicates, spessartite and rhodonite. The alteration takes the form of metasomatic replacement of the gonditic rocks. A careful consideration of all the available evidence leads to the conclusion that this replacement was not superficial, but took place in depth before denudation brought the gonditic bands and associated ore deposits to the surface.

As the formation of the observed manganese ores—braunite, psilomelane, and hollandite, chiefly—from the silicate minerals is an oxidation process, it is necessary to look for a deep-seated source of oxygen. The oxygen liberated

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[1] Memoirs, Geological Survey of India, Vol. XXXVII, 1909.

[2] Loc. cit., chapters XV–XVII.

[3] Records, Geological Survey of India, Vol. XXXIII, pp. 168-172, 1906.

[4] Memoirs, Geological Survey of India, Vol. XXXVII, p. 315.

[5] Loc. cit., pp. 306, 325.

[6] Assuming the manganese oxide to have been the hydrated peroxide. It would be easy, of course, to construct equations for the case of the hydrated sesquioxide.

in the original formation of the spessartite and rhodonite would obviously still be available if pressure had prevented its escape.

Carbon dioxide is also required to explain certain features of the change;[1] but it is at first sight not so easy to provide. We must remember, however, that it is an assumption that the original manganiferous sediments contained their manganese entirely in the form of oxides; there may have been carbonate present as well, and this, when subjected to metamorphism, would have combined with silica to form rhodonite with liberation of carbon dioxide. Secondly, in all parts of India where the gondite series has been found—in a belt some six hundred miles long stretching from Jhabua and Narukot on the west through the Central provinces to Gangpur in Bengal on the east—crystalline limestones have been found in moderately close proximity. A portion of the carbon dioxide supposed to have been locked up in these limestones at the time of their formation (see below) may have been diverted to the manganese-bearing rocks. The former explanation seems, on the whole, the more satisfactory. It is probable that the manganese ore bodies of the Central provinces originated from two sources. In part they are the products of the direct metamorphism in depth of relatively pure oxide sediments (primary ores); and in part they are due to the metasomatic replacement of gondite and rhodonite-rock, also in depth (deep secondary ores), through the agency of oxygen and carbon dioxide, which were given freedom to work on the release of the pressure that effected the original metamorphism.

That a portion of the manganese ores of the Central provinces is of great antiquity, and was probably formed in depth, is conclusively proved by the case of the Gowari Warhona manganese ore quarry in the Chhindwara district. A pegmatite vein that traverses this ore deposit contains a picked-up angular fragment of manganese ore identical with that forming the walls of the vein. There is no reason to assign to the pegmatite any other age than Archæan.[2]

Now let us turn to the crystalline limestones. Some years ago, in a paper on the petrology of a portion of the Chhindwara district, Central provinces, I discussed the origin of the varied Archæan limestones described therein. Excluding the manganiferous varieties, which constitute a connecting link between the limestones and the gondite series, there are two main types. One is closely associated with a series of calc-gneisses described under the name of quartz-pyroxene-gneisses. In this type, which often contains various accessory minerals, such as diopside, epidote, actinolite and essonite, the carbonate mineral is entirely calcite. There are many indications of every gradation from the quartz-pyroxene-gneisses, through calciphyres, to pure crystalline limestones; and it is possible to regard all these limestones as products of the chemical alteration or replacement of the gneisses under the influence of solutions carrying carbon dioxide and, some-

[1] Memoirs, Geological Survey of India, Vol. XXXVII, p. 359.
[2] Records, Geological Survey of India, Vol. XLI, p. 7, 1912.

times, an alkaline carbonate in addition.[1] The purest limestone would be the final product. But perhaps a more likely view[2] is that, analogously with the case of the gondite series, these calcareous rocks have been formed by the metamorphism of a banded series of calcareous sediments of various degrees of purity. The least pure yielded the quartz-pyroxene-gneisses, and the purest the pure marbles, the two extremes being linked up by the calciphyres. The numerous cases of replacement of the gneisses by calcite may then be explained as due to the attack of the imprisoned carbon dioxide on removal of the pressure that originally isolated it when the calciphyres and gneisses were formed. This reversed replacement may lead, of course, to the formation of pure marbles; and thus, analogously with the case of the manganese ores, we must admit the possibility of pure crys lline limestones of two distinct origins. One is *deep-seated primary limestone*, and the other *deep-seated secondary limestone*.

Turning to the other group of limestones in this district, these are found to contain, in addition to calcite, abundant dolomite and serpentine and also, very frequently, diopside, phlogopite, chondrodite, and spinel. From the microscopic evidence it appears that these serpentinous limestones have been formed entirely by chemical alteration of original lime-magnesia silicate rocks of which the chief minerals were diopside, phlogopite, chondrodite, and spinel. However, no completely unaltered example of the original rocks has been found. The calcite, dolomite and serpentine are thus all secondary minerals. If such a rock as that deduced above can be regarded as a metamorphosed sediment (which, however, one feels inclined to doubt), then its carbonation also may be explained as due to the carbon dioxide liberated at the time of its original metamorphism having reversed the chemical pr esses involved in this metamorphism.

In the course of my own work I have not yet encountered any other associations of rocks or minerals illustrative of this principle of reversal of chemical action on release of pressure, and chemical attack by the very gases or liquids that were liberated from combination on the incidence of pressure. Also, as this communication is being written in camp, away from libraries, it is not possible for me to consult the literature of ore deposits or petrology for examples outside India in which this principle may have been operative. But I suggest that it may be of use in exp' ining some of the phenomena observed in iron ore deposits of combined chemical and sedimentary origin, e.g., in the Lake Superior region.

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[1] Records, Geological Survey of India, Vol. XLI, pp. 170-172.
[2] Memoirs, Geological Survey of India, Vol. XXXVII, p. 298.

PRIMÄRE UND SEKUNDÄRE ERZE UNTER BESONDERER BERÜCKSICHTIGUNG DER "GEL-" UND DER "SCHWERMETALLREICHEN" ERZE.

VON

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I. BEDEUTUNG DER GELE BEI DER ENTSTEHUNG SEKUNDÄRER UND PRIMÄRER ERZE.

A. Allgemeines über die Entstehung der Gelerze.

Der erste, der die Lehre von den Gelen auf die Erze anwandte, war CORNU. In einem Aufsatze in der ***Zeitschrift für praktische Geologie*** beschäftigte er sich eingehend mit dem von mir aufgestellten Begriff der *Leiterze* und führte die Trennung der Erze der verschiedenen Schwermetalle in Gele und kristalline Erze durch. Nach dem damaligen Stande der Kenntnisse war er zu der Annahme berechtigt, dass die Gele *nur* bei der *sekundären* Verschiebung der Metallgehalte auf Erzlagerstätten eine Rolle spielen, also keine primären Lagerstätten bilden können.

Auf CORNUS Resultaten weiterbauend, zeigte ich in der zweiten Auflage der ***Untersuchung und Bewertung von Erzlagerstätten*** (Stuttgart, FERDINAND ENKE, 1911), dass es auch *primäre kolloide* Erze gibt, die *erstmalige Erzkonzentrationen* darstellen.

Seitdem habe ich mich mit den fraglichen Erzen in chemischer und petrographischer Beziehung weiter beschäftigt. An dieser Stelle will ich kurz die Richtungen, in denen im Erzlagerstätteninstitute in Berlin gearbeitet wird, und einige Resultate von allgemeiner Bedeutung anführen.

Für die kolloiden, ursprünglich amorphen Erze, welche sich aus den bei der Verwitterung entstehenden sogenannten "Solen" bilden, gebrauche ich den Namen *Gelerze*. Auch wenn sie durch nachträgliche Veränderung kryptokristallin geworden sind, unterscheiden sie sich in ihren physikalischen Eigenschaften scharf von den ***ursprünglich*** kristallinen Erzen, mit denen sie z. T. gleiche chemische Zusammensetzung haben.

Die kolloiden Erze können nachträglich in kristalline übergehen; so wird z. B. das Gelerz Polianit häufig von jüngeren Pyrolusitgängen und das Gelerz Brauneisen von Nestern und Trümern kristallisierten Eisenhydrates durchzogen. Hier liegen meist wässerige Umlagerungen vor.

Fast noch wichtiger sind aber die fast ganz allgemein für Gele giltigen Beobachtungen, dass *Erhöhung der Temperatur* und *Erschütterungen* häufig genügen um ein Gel in seiner ganzen Masse kristallin werden zu lassen.

Das Erkennen der kristallinen Doppelgänger der Gelerze durch CORNU hat unsere Kenntnis von der Entstehung und Zusammensetzung namentlich oxydierter und hydratischer Eisen- und Manganerze wesentlich geklärt.

Die Gele haben die Eigenschaft auf die Schwermetall- u.s.w. lösungen *adsorbierend* einzuwirken. Diese Eigentümlichkeit macht das Erkennen ihrer chemischen Zusammensetzung in vielen Fällen schwierig. So kann man häufig nicht feststellen, ob ein Gelerz eine selbständige chemische Verbindung darstellt oder ein Gemenge bildet, welches aus zwei Komponenten besteht, nämlich erstens einem Gel und zweitens der von ihm adsorbierten Schwermetallverbindung. Ich möchte hierfür die Namen "*Gelgrundmasse*" und "*adsorbierte Durchtränkungssubstanz*" vorschlagen. Zu dieser Art von Gelerzen gehören z. B. die silikatischen Nickelerze, mit deren Untersuchung ich mich eben—gemeinsam mit BEYSCHLAG—bei der Abfassung der Monographie über die Nickelerzlagerstätten von Frankenstein (Schlesien) beschäftigte. Sie bestehen—wie schon früher vermutet wurde—aus einem "Nichterz"- Gel als Gelgrundmasse und einer Nickelverbindung als adsorbierte Durchtränkungssubstanz. Näheres wird Herr KRAFT, ein Schüler. Prof. KEMPS, nächstens veröffentlichen, der bei mir die Beziehungen zwischen den Lagerstätten amorphen Magnesits und denjenigen silikatischer Nickelerze zu Promotionszwecken bearbeitet.

Auch der umgekehrte schon CORNU bekannte Fall kommt vor, dass *Gelerze nichtmetallische Stoffe adsorbieren*, wie z. B. Gelmanganerz Barium- und Kaliumverbindungen.

Über die physikalischen und chemischen Bedingungen dieser Adsorptionsprozesse werden gegenwärtig an der Bergakademie zu Berlin interessante Versuche angestellt, zu denen Prof. WÖLBLING und ich einen meiner Schüler anregten.

Die bei der Durchtränkung der Massen auftretenden Adsorptionsvorgänge sind im Dünnschliff vorzüglich zu beobachten. Wie ich in vielen Fällen feststellen konnte, sind sie mit weitgehenden metasomatischen Prozessen verbunden, die zur fast vollständigen Verdrängung der ursprünglichen Substanz führen können.

Adsorption und Metasomatose gehen also Hand in Hand, die erstere ist eine sehr günstige Vorbedingung für die letztere, beide sind so eng miteinander verknüpft, dass man von einer "*Adsorptionsmetasomatose*" sprechen muss.

Da die Verwitterungsvorgänge die Gelerze hauptsächlich erzeugen und die Verwitterung für die *verschiedenen Breiten* verschieden ist, werden sich auch Verschiedenheiten im Auftreten der Gelerze in dieser Beziehung nachweisen lassen. Ich komme auf diesen Punkt noch später zurück. Hier muss ich aber hervorheben, dass die Frage aufs engste mit dem Studium der sekundären Metallverschiebungen verknüpft ist, die ja ausschliesslich durch die Verwitterung bedingt werden. Eine sehr wünschenswerte systematische und erschöpfende Bearbeitung der sich aus der *verschiedenen Breitenlage der Erzvorkommen ergebenden Unterschiede* wird auch unsere Kenntnis der *Gelerzbildung* wesentlich fördern.

B. Durch Deszensionslösungen entstandene Gelerze.

Bisher sind wir nur bei diesen zu einwandfreien Resultaten gelangt. Bei den Verwitterungsprozessen entstehen Hydrosole, aus denen sich die Gelerze bilden. Alle von CORNU angeführten Erze sind derartige Oberflächenbildungen. Sie werden also *besonders häufig* in der Oxydationszone auftreten, sind aber nicht, wie CORNU annahm, auf diese *beschränkt*.

Die Cornuschen Ergebnisse lassen sich wie folgt zusammenfassen: Gelerze sind auf die Nähe der Erdoberfläche beschränkte, amorphe, oxydische oder hydratische, erdige, ockrige oder mehr oder weniger verfestigte Erzmassen.

Die neueren Untersuchungen beschäftigen sich hauptsächlich mit der Frage, *bis zu welcher Tiefe Gelerze überhaupt vorkommen*. Die Beantwortung hängt aufs engste mit den Veränderungen zusammen, welche durch Oberflächenwasser gebildete Verwitterungslösungen beim Niedersinken erleiden.

Bei diesen Vorgängen müssen wir im allgemeinen zwischen der *Zersetzung nichtsulfidischer und sulfidischer Erze* unterscheiden.

Aus den ersteren werden sich keine leicht reduzierbaren Lösungen bilden; es fällt dann das wichtigste Unterscheidungsmoment zwischen den für die Oxydations- und die Zementationszone charakteristischen Schwermetalllösungen weg. Es fehlt ausserdem die reduzierende Wirkung der für die Zementationsvorgänge unerlässlichen primären Sulfide. Die Eigenschaften der Lösungen bleiben vielmehr im Prinzip unverändert. Diese sekundären Metallverschiebungen können *mindestens bis zum Grundwasserspiegel* reichen. Namentlich in Gebieten, die durch irgendwelche tektonische Ursachen in beständiger Hebung begriffen sind, in denen also der Grundwasserspiegel relativ sinkt, können dann recht bedeutende Lagerstättenhöhen für die Neubildung in Frage kommen. Da eine den Gelerzen, wie später gezeigt werden wird, bei längerer Einwirkung schadende höhere Azidität der Lösungen hier keine Rolle spielt, *können sie sich in einer bedeutenden Lagerstättenhöhe bilden.*

Komplizierter sind die Verhältnisse bei Lagerstätten mit *reichlich sulfidischen* Erzen. Hier sind, wie z. B. in Rio Tinto, z. T. bedeutende Massen von Schwefel konzentriert worden. Würde der gesamte, bei der Verwitterung in Schwefelsäure übergehende Schwefel auf der Lagerstätte bleiben, so wäre wegen der bedeutenden Azidität die Gelegenheit zur Gelerzerhaltung nicht besonders günstig. Wir finden nun aber im eisernen Hut dieser Lagerstätten enorme Mengen von Geleisenerz. Es sind nämlich hier bedeutende Mengen von Schwefelsäure weggeführt worden, denn Sulfate treten nur in ganz verschwindender Menge auf. Die Wegführung erfolgte oberflächlich, da der Schwefel schon in geringer Tiefe noch erhalten ist. Ein Zeuge der Säurewirkung ist das zerfressene Nebengestein, welches häufig nur noch ein Quarzskelett bildet.

Nur ein kleiner Teil der Sulfatlösung sank auf dem Erzkörper in die Tiefe und wurde durch die noch unzersetzten primären Sulfide nach Verbrauch des Sauerstoffs in der bekannten Weise reduziert.

Wie tief finden bei Rio Tinto die Gelerze und zwar ausschliesslich Geleisenerz? Nur so tief als Sauerstoff noch wirksam war, also beschränkt auf die Oxydationszone. *Mit den hier typischen Zementationserzen sind nach unserer heutigen Kenntnis keine Gelerze vergesellschaftet.* Die Azidität der niedersinkenden Lösungen dürfte zu gross für die Gelerhaltung gewesen sein.

Schliesslich bedürfen noch eigenartige Erzumwandlungen der Erklärung, die man auf den Siegerländer Spateisengängen bis zu bedeutender Tiefe findet, ohne dass irgendwelche Begleiterscheinungen auf umfangreichere Zersetzungsvorgänge hinweisen. Es ist dies die *Roheisen- und Eisenglanzbildung im frischen Spateisen.* BORNHARDT erklärt sie in seiner Monographie der Siegerländer Gänge (1912) als unmittelbar im wassererfüllten Gangraum durch solche Reagentien erfolgt, welche von der Oberfläche nach der Tiefe vordrangen. In Zeiten grosser Trockenheit z. B. im Oberrotliegenden entstanden nach ihm konzentrierte Salzlaugen an der Oberfläche die vermöge ihres hohen spezifischen Gewichtes auf den Gebirgsspalten in die Tiefe sanken und vermittels des von ihnen absorbierten Sauerstoffes oxydierende Wirkungen ausübten. Der genannte Autor weist aber selbst darauf hin, dass das Fehlen irgendwelcher Reste derartiger Salzlösungen auffällig ist.

Ich habe mich im Gegensatze hierzu in einem Anhange der Bornhardtschen Arbeit der Ansicht WÖLBLINGS angeschlossen, nach welcher die Annahme gelartiger Lösungen näher liegt. Sie erklären auch die auffallende Erscheinung des vollständigen Fehlens irgendwelcher Oxydationsprodukte, die man, wenn die Annahme BORNHARDTS richtig wäre, im so leicht zu oxydierenden Spateisen finden müsste. Die sauerstoffhaltigen Gellösungen haben dagegen die Eigentümlichkeit, dass sie den Sauerstoff *nicht* an die älteren Erze abgeben.

Bei derartigen Prozessen darf man nicht nur an die Zirkulation der Lösungen auf Spalten denken, sondern man muss *umfangreichere Durchtränkungen grösserer Massen ohne grössere Hohlräume* annehmen. Die Umwandlungen treten dann nicht gang-, sondern herdförmig auf und scheinen in keinerlei Beziehungen zu Spalten zu stehen.

Derartige Durchtränkungen mit spezifisch schweren Lösungen, die von oben niedersinken, können sich *bis tief unter den Grundwasserspiegel* erstrecken. Es treten dann Gelerze ganz unvermittelt in der primären Zone Hunderte von Metern unter dem Grundwasserspiegel auf, *die Tiefe hängt hauptsächlich von dem spezifischen Gewicht der Lösung ab.*

Die Gelerze sind also nicht nur auf die Nähe der Erdoberfläche beschränkt, wo sie am häufigsten vorkommen, sondern sie finden sich bis zu bedeutenden Tiefen. Sie kommen meist in der Oxydationszone vor, können sich aber auch noch in der primären bilden.

C. Erfahrungen über durch Aszension entstandene Gelerze.

Ich kenne bisher kein einwandfreies Beispiel für die Entstehung von Gelerzen durch Aszension, kann deshalb nur die *Möglichkeit* ihres Auftretens diskutieren. Am günstigsten für ihre Bildung sind also die bei den Verwitterungsprozessen vorhandenen Bedingungen wie *niedrige Temperatur* *niedriger Druck, Gegenwart von Sauerstoff* u. s. w. Diese drei Eigenschaften haben die aszendierenden Lösungen so gut wie nie in bedeutender Tiefe, sondern erst in der Nähe der Oberfläche, nachdem sie von dieser und den hier herrschenden Bedingungen beeinflusst worden sind. *In der Tiefe sind also die Bedingungen für die Gelbildung ungünstig.*

Die *theoretische Möglichkeit* der Bildung der Gele durch Aszensionslösungen lässt sich aber nicht bestreiten. In dieser Beziehung sind Versuche des Professor WÖLBLING an der Bergakademie Berlin recht lehrreich. Seit mehreren Jahren hebt er ein Kieselsäuregel, welches durch Salzsäure aus Wasserglaslösung abgeschieden wurde, bei einer Temperatur zwischen 80° und 100° auf; es hat noch die Gelnatur bewahrt, wenn auch bereits eine Abspaltung von Wasser stattfand. Damit ist der Beweis geliefert, dass *gewisse Gele längere Zeit eine höhere Temperatur* aushalten. Der durch Experiment nachgewiesene Zeitraum von mehreren Jahren ist allerdings in der Geschichte der Erdrinde nur kurz und die angewandten Temperaturen sind keine hohen im Vergleich zu den in grösserer Tiefe herrschenden.

Viele Gele können übrigens bei 100° entstehen, sie haben aber – namentlich die sulfidischen Gele der Schwermetalle—das Bestreben schnell in kristalline Körper überzugehen.

Auch der *Einfluss des Druckes* auf die Gele, der ebenfalls einen wichtigen Faktor bei aszendierenden Lösungen bildet, ist experimentell noch nicht genügend erforscht. Über einige Resultate wird einer meiner Schüler dipl. Ing. NICOLAI in seiner Promotionsarbeit berichten.

Bei allen diesen Versuchen fehlt uns aber vor allen Dingen ein Faktor, den die Erdgeschichte—und nur diese—zur Verfügung hat, nämlich *die geologischen Zeiträume.*

Unsere bisherige Kenntnis der durch Aszension entstandenen Gelerze lässt sich also dahin zusammenfassen, dass man bisher kein einziges derartiges Beispiel kennt und dass die in grösserer Tiefe vorhandenen Bedingungen keine für die Gelbildung günstigen sind.

D. Kennen wir neben den sekundären auch primäre Gelerze?

Die Begriffe *primäre* und *sekundäre* Erze bedürfen hier zunächst der Definition. *Primäre Erze* sind nach meiner Auffassung:

a) die der *ursprünglichen* natürlichen Konzentrationen und

b) die durch jüngere *aszendierende* Lösungen bewirkten Neuentstehungen und Metallverschiebungen (innere Lagerstättenmetasomatose z. T.)

Sekundäre Erze entstehen ausschliesslich durch deszendierende Oberflächenwässer (innere Lagerstättenmetasomatose z. T.)

CORNU kannte also ausschliesslich sekundäre Gelerze.

Ich habe schon in früheren Veröffentlichungen darauf hingewiesen, dass es auch primäre Gelerze gibt, z. B. die *Raseneerze von Eisen und Mangan.* Hierher gehört auch der *Bauxit*, welcher in den meisten Fallen metasomatisch aus Kalkstein durch Lösungen gebildet wird, die bei der Verwitterung entstehen.

Zu den primären Erzen mit Gelcharakter muss ich auch gewisse *lateritische* Bildungen rechnen, bei denen es zu derartig bedeutenden Eisenerzanreicherungen gekommen ist, dass an den Abbau gedacht wird. Ich kenne derartige Vorkommen in Europa im Osten Sardiniens bei Jerzu. Auf diese hochinteressanten Lagerstätten machte mich NOVARESE in Rom aufmerksam.

In diesen Fällen bedingen die Verwitterungsvorgänge an und für sich die Konzentrationen, da diese aber ursprünglich sind, müssen die genannten Gelerze als primäre aufgefasst werden.

Etwas anders liegen die Entstehungsbedingungen bei den bereits oben mehrfach erwähnten *silikatischen Nickelgelerzen*, die ebenfalls als primäre aufgefasst werden müssen. Sie sind unser schönstes Beispiel für Lateralsekretion im engeren Sinne des Wortes und entstanden—soweit genaue Untersuchungen vorliegen—durch jüngere Verwitterung. Auch bei Frankenstein konnten BEYSCHLAG und ich diese Genesis nachweisen. Während aber bei den oben angeführten Beispielen die Lösungen nur ganz oberflächlich Erz konzentrierten, findet bei den silikatischen Nickelerzen eine Tiefenwirkung statt, derart dass eine intensive Zersetzung des Serpentingesteines an Spalten von der Oberfläche nach der Tiefe platzgreift. Diese Erscheinung lässt sich bei Frankenstein, wo Quarz- und Chalcedongänge den Serpentin zerrütteten, vorzüglich beobachten. Der Absatz der Nickelgelerze erfolgte gangartig oder in Form ganz unregelmässiger Imprägnationsmassen, die häufig nach unten trogförmig endigen.

Hier war der Nickelgehalt ursprünglich in Silikatform im Olivin enthalten, man hat aber kein Recht dieses Mineral als „Erz" zu bezeichnen und auch bei der Serpentinisierung fand keine Nickelkonzentration statt. Nickel ist auch nicht—wie von vielen Forschern angenommen wird—der leichtest extrahierbare Bestandteil des Serpentins, bei Frankenstein konnte ich vielmehr den Nachweis führen, dass die Magnesitextraktion wesentlich früher erfolgte. Der Einfluss der Tagewässer bildete erst später die Nickellösungen, welche die silikatischen Nickel-Gelerze entstehen liessen. Wir müssen sie zu den primären Erzen rechnen, die im allgemeinen gangförmig auftreten.

Aus diesen Erwägungen ergibt sich, dass primäre Gelerze nutzbare Lagerstätten bildend auftreten können und zwar entstanden sie unmittelbar an der Oberfläche oder durch deszendierende Lösungen.

Dieses Resultat berechtigt zu folgendem Schluss:

Als Verwitterungsprodukte müssen die Gelerze von klimatischen Verhältnissen abhängig sein, d. h. die Zusammensetzung muss sich beispielsweise bei rezenten Lagerstätten mit dem Breitengrade ändern. Ich erinnere hier an den Unterschied zwischen unseren Raseneisenerzen und dem Laterit der Tropen inbezug auf den Tonerdehydratgehalt: bei uns fast ausschliesslich Eisenanreicherung, dort zugleich Bauxitisierung.

Ein genauer und kritisch durchgeführter Vergleich der Zusammensetzung unter verschiedenen klimatischen Verhältnissen entstandener primärer Gelerzlagerstätten dürfte wichtige Ergebnisse liefern.

II. DIE ENTSTEHUNG DER SCHWERMETALLREICHEN SULFIDE UND ERZE.

A. *Allgemeines.*

Wie allgemein bekannt, bilden viele Schwermetalle—z. B. Kupfer, Silber, Gold u. s. w.—neben den Erzen mit gewöhnlichen Metallgehalten, welche man gewohnt ist in den primären Teufen zu finden, unter günstigen Umständen *abnorm metallreiche*; wir lernen die besonders beim Studium der Zementationszonen kennen.

Diese *reichen* Erze gehören drei Gruppen an: Es sind erstens die *schwermetallreichen Sulfide* u. s. w. wie Silberglanz, Rotgildigerz, Kupferindig, Buntkupfererz, Kupferglanz u.s.w., oder zweitens *gediegene Metalle*, die geringere Verwandschaft zum Sauerstoff haben wie z. B. Gold, Silber oder schliesslich drittens *Gemenge der letzteren mit Normal-Schwermetallsulfiden* wie z. B. Gold und Schwefelkies, Silber und Bleiglanz, Rotgildigerz und Bleiglanz.

Die Genesis dieser drei Gruppen ist nicht ganz gleich: Die schwermetallreichen Sulfide überziehen, wie man im Dünnschliff einwandfrei feststellen kann, gewöhnlich zunächst die älteren Normalsulfide, deren Klüfte sie ausfüllen. In einem späteren Stadium verdrängen sie aber ihre Wirte, so dass schliesslich derbes *Reich*sulfid entsteht, dessen zementationsmetasomatische Genesis man nur unter besonders günstigen Umständen bei starken Vergrösserungen an der Maschenstruktur oder an winzigen Resten der älteren Normalsulfide erkennen kann. Hat man bei der Auswahl der Präparate Glück, so lassen sich alle Übergänge feststellen zwischen dünnen Überkrustungen und Hohlraumauskleidungen in Normalsulfiden, durch alle möglichen Stadien der Metasomatose bis zum Derb-Reicherz, dem Niemand ohne weiteres die Entstehung durch Metasomatose ansehen würde.

Besonders interessante Vorgänge konnte ich bei den Kupfererzen im Dünnschliff feststellen. Auf den meisten Lagerstätten kommt als primäres Kupfererz bekanntlich kupferhaltiger Schwefelkies oder ein Gemenge von Schwefelkies mit mehr oder weniger Kupferkies vor. In der Zementationszone entsteht durch Metasomatose in der Regel aus dem Gemenge zunächst reiner Kupferkies, im nächsten Stadium der Umwandlung Buntkupfererz und schliesslich Kupferglanz, also eine Reihe beginnend bei den kupferärmeren Erzen und endigend bei den kupferreichen. Bei jeder Verdrängung mussten die Lösungen Kupfer abgeben und Schwefel aufnehmen. Bei diesen Prozessen handelt es sich nicht nur um eine freie Zirkulation der Schwermetalllösungen auf Spalten und in Hohlräumen, sondern es spielen die *Durchtränkungen grosser Massen mit Lösungen und die Verdrängungen spezifisch leichterer durch spezifisch schwerere eine wichtige Rolle.*

Die die zweite Gruppe bildenden *gediegenen* Metalle mit geringer Verwandschaft zum Sauerstoff fand ich vor allem als Hohlraumausfüllungen und Überkrustungen sowohl von nichtmetallischen Mineralien als auch von Gesteinen, die zur Lagerstättenausfüllung gehören. Eine Verdrängung ihrer Wirte konnte ich bisher nicht feststellen, die Vergesellschaftung mit Gelteisenerz ist dagegen eine recht häufige Erscheinung, da diese Erze besonders häufig an der Grenze der Oxydations- gegen die Zementationszone vorkommen.

Drittens treten *Gemenge gediegener Metalle mit Normalschwermetallsulfiden* auf, unter ihnen sind Gold mit Schwefelkies und Silber mit Bleiglanz am häufigsten. Auch hier fand ich in den zahlreichen Dünnschliffen nur Überkrustungen und Hohlraumausfüllungen der jüngeren Edelmetalle auf bezw. in den älteren Normalsulfiden.

Ich möchte die beiden zuletzt angeführten Beobachtungen des Fehlens von metasomatischen Prozessen nicht derart aufgefasst wissen, dass ich die *Möglichkeit ihres Auftretens* **bestreite**, *jedenfalls scheint mir aber der Beweis geliefert zu sein, dass bei diesen Gruppen die Metasomatose bei weitem nicht die Rolle spielt wie bei der Entstehung der reichen Schwermetallsulfide*

B. Entstehung der sekundären reichen Sulfide durch Deszension.

Die Bildung der deszendierenden Schwermetalllösungen in der Oxydationszone der Erzlagerstätten und ihre Reduktion durch die primären Metallsulfide in der Zementationszone ist heute Gemeingut aller Lagerstättengeologen geworden. Die Zahl der Forscher, die sich mit der Frage beschäftigen, ist zu gross als dass ich sie hier aufzählen möchte. Ich will aber nicht verfehlen darauf hinzuweisen, dass DE LAUNAY in Europa zu den Pionieren gehört, deren Arbeiten mich zu meinen Forschungen anregten und dass mancher neue Weg ganz besonders von ausgezeichneten Gelehrten der Neuen Welt gewiesen wurde. Trotzdem sind die Forschungsergebnisse noch bei weitem nicht erschöpft.

Ich möchte hier auf folgende weiterer Klärung bedürfende Fragen kurz eingehen:

a) Bis zu welcher Tiefe kommen derartige Verbindungen vor?
b) Welche Rolle spielt dabei die Tektonik?
c) Welchen Einfluss haben Klima, Abrasion u. s. w.?
d) Wie ist ihre Bildung von Spalten aus in grosser Tiefe zu erklären?

Zu *a)*: Man kann die meisten Erfahrungen in den Satz zusammenfassen, dass sich Oxydationserze so lange bilden als Sauerstoff vorhanden ist und Zementationserze etwas tiefer durch Reduktion der Sulfide entstehen.

In der Regel nimmt man an, dass diese Umwandlungen lediglich durch nach der Tiefe auf Hohlräumen zirkulierende Lösungen hervorgebracht werden, und man ist deshalb gewohnt als untere Grenze dieser Umwandlungen den *Grundwasserspiegel* anzusehen.

Wenn nun auch zweifellos zur Bildung der Oxydationserze Sauerstoff notwendig ist, und sein Verbrauch die Möglichkeit der weiteren Bildung dieser Erze ausschliesst, so bedarf die *untere Grenze der Zementationserze* zweifellos einer Revision.

Auf den Erzlagerstätten spielen nicht nur die freizirkulierenden Lösungen, sondern auch die Durchtränkungen eine Rolle. Auch wenn keine grösseren Hohlräume in der Lagerstättenmasse vorhanden sind, findet eine Zirkulation des Grundwassers statt und zwar werden—wie ich bereits ausführte—die spezifisch leichteren Lösungen durch die spezifisch schwereren verdrängt. *Die auf der Lagerstätte nach der Tiefe sinkenden Schwermetalllösungen können* *also unter den Grundwasserspiegel gelangen und dort beispielsweise metasomatische Verdrängungen älterer Erze bewirken.*

Da die Verdrängung einer Lösung durch eine schwerere viel langsamer vor sich geht als die Zirkulation in Hohlräumen, spielt der Grundwasserspiegel insofern eine bedeutende Rolle, als er die *untere Grenze des der schnellen Umwandlung* unterworfenen Lagerstättenteiles darstellt. *Die untere Grenze der Umwandlung überhaupt bildet er aber nicht.*

Diesem Gesichtspunkte muss in allen Fällen Rechnung getragen werden, wo Zementationserze bis zu bedeutenden Tiefen unter den Grundwasserspiegel reichen und geologisch sehr alte Lagerstätten vorliegen.

Zu b): *Tektonik und Grundwasserspiegel* hängen aufs engste mit einander zusammen, derart dass jede Verschiebung der Lagerungsverhältnisse auch eine Verschiebung des Grundwasserspiegels bedingt. Die Veränderungen können mehr oder weniger schnell vor sich gehen. So verursachen die säkularen Hebungen und Senkungen zwar langsame aber recht bedeutende relative Senkungen bezw. Hebungen des Grundwasserspiegels, tektonische Gräben und Horste dagegen veranlassen meist schnellere relative Hebungen und Senkungen des Grundwassers. Diese Verschiebungen beeinflussen die offene Zirkulation der auf der Lagerstätte in die Tiefe sinkenden Lösungen und damit die durch sie bewirkte Mineralbildung.

Auffallende Abweichungen von der Norm der Erscheinungen können aber nur erklärt werden, wenn die Tektonik eines Gebietes feststeht. So ist es z. B. ganz zwecklos die Genesis der bis zu bedeutenden Tiefen reichenden Silberreicherze von St. Andreasberg zu diskutieren, so lange es dem Stratigraphen und Tektoniker nicht möglich ist zu entscheiden, ob der zwischen den beiden Grenzruscheln liegende Gebirgskeil, in dem ausschliesslich die Silbererzgänge auftreten, im Ganzen ein Senkungs- oder Hebungsgebiet darstellt.

Mein Urteil geht dahin, dass das Auftreten der Zementationserze in der Tiefe auf *Senkung* schliessen lässt., dass also ein ähnlicher Fall wie bei Butte, Montana, vorliegt.

Zu c): Die *Abhängigkeit der sekundären Metallverschiebungen von der Abrasion* ist allgemein bekannt, die Intensität der letzteren bedingt die *Menge* der Oxydations- und Zementationserze.

Wenig erforscht sind dagegen die durch *klimatische Unterschiede* bedingten Abweichungen in der Ausbildung der Oxydationszone, auf die ich bereits oben hinwies. Hier dürften genaue Untersuchungen recht lohnende Resultate ergeben unter der Voraussetzung, dass genetisch gleichartige Lagerstätten verschiedener Breiten mit einander verglichen werden.

Da auch der Grad der Abrasion durch das Klima bedingt wird, lassen sich die beiden Faktoren nicht von einander trennen. Das Fehlen bedeutenderer Oxydationsvorgänge auf den norwegischen Kieslagerstätten einerseits und die beträchtliche Höhe des Eisernen Hutes auf den genetisch gleichartigen Kieskonzentrationen der Sierra Morena Spaniens und Portugals andererseits wird nicht nur durch den hohen Temperaturunterschied bedingt, sondern zugleich in hervorragender Weise durch den Abrasionsunterschied: In Skandinavien liess es die Gletscherabrasion nicht zur Ansammlung grösserer Oxydationsmassen kommen, deren Entstehung die niedere Temperatur sowie so nicht günstig war. In Spanien wurden die Produkte des an und für sich durch die höhere Temperatur begünstigten Oxydationsvorganges nur langsam durch die Niederschläge zerstört.

Zu d): Das Auftreten typischer Oxydations- und Zementationserze in der primären Zone hat in einzelnen Fällen das höchste Interesse der Lagerstättenforscher erregt.

Bekannt ist das Eindringen der Zementationserze in die primäre Zone namentlich in solchen Fällen, wo die sekundären Metallverschiebungen noch nicht bis zum Grundwasserspiegel vorgedrungen sind. Durch die Volumenveränderungen bei den Zementationsvorgängen bilden sich in die primären Erze hineinreichende Spalten, auf denen die Schwermetalllösungen niedersinken, die Zementationserze entstehen also hierbei durch Deszension.

Oben habe ich darauf hingewiesen, dass sich auch unter dem Grundwasserspiegel Zementationserze bei der Durchtränkung der ursprünglich Grundwasserführenden primären Erze bilden können. Die neuerer Untersuchungen haben gezeigt, dass die dadurch bewirkten Mineralneubildungen nicht *gleichmässig* fortzuschreiten brauchen, sondern sich auf in chemisch-geologischer Beziehung besonders geeignete Stellen beschränken können. Es entstehen dann „Umwandlungsherde" inmitten unverändert gebliebenen Materials, ohne dass Zubringerspalten zu sehen sind.

Schliesslich kommen Oxydations- und Zementationserze in gesetzmässiger Anordnung *an Spalten* vor, die sich durch irgendwelche—meist tektonische—Ursache im Nebengestein bildeten und bis in die primäre Zone aufrissen. Von solchen Spalten kann das Grundwasser derart beeinflusst werden, dass das Gebiet in der Nähe der Spalte abgetrocknet wird. Gelangen später auf der Spalte Oberflächenwässer in dieses Abtrocknungsgebiet, so wirken sie von der Spalte aus genau so, wie die Atmosphärilien von der Oberfläche aus. So lange Sauerstoff vorhanden ist, bilden sich zu beiden Seiten der Spalte Oxydationserze und nach Verbrauch des Sauerstoffes in etwas grösserer Entfernung Zementationserze. Waren die Lösungen bereits sauerstofffrei aber schwermetallhaltig, so entstanden ausschliesslich Zementationserze.

Hier liegen also Verwitterungsprozesse in grösserer Tiefe unter besonders günstigen Umständen vor.

C. Entstehung primärer schwermetallreicher Erze durch Aszension.

Die Studien über die Leiterze der Oxydations-, Zementations- und primären Zone haben unsere Kenntnis des Auftretens einer grossen Anzahl oxydischer und sulfidischer Erze bedeutend erweitert. Wenn man bei der leider so beliebten Anwendung der Superlative und der Worte "ausschliesslich" und "nur" vorsichtig ist, kann man schon jetzt eine Fülle von Gesetzmässigkeiten aufstellen, die nicht nur für die Wissenschaft wichtig, sondern zugleich für die Praxis bei der Untersuchung und Bewertung von Erzlagerstätten von unschätzbarem Werte sind. Da ich an anderen Stelle auf den jetzigen Stand unserer Kenntnisse eingegangen bin, will ich mich hier nur mit der *Möglichkeit der Bildung schwermetallreicher Sulfide* unter solchen Bedingungen beschäftigen, dass sie zu den primären gerechnet werden müssen.

Die allgemein anerkannten wesentlichen Momente der Entstehung schwermetallreicher Erze in der Zementationszone sind Schwermetalllösungen ohne freien Sauerstoff einerseits und ältere reduzierende Normalsulfide andererseits. Nach unseren bisherigen Erfahrungen sind die wirksamen Lösungen allerdings deszendierende, aber die Herkunftsrichtung dürfte für den Mineralbildungsprozess gleichgiltig sein.

In welchen Fällen primärer Erzbildung werden auch bei aszendierenden Lösungen die obigen beiden Bedingungen erfüllt? Ich kenne vorzugsweise zwei, nämlich: a) Minerallösungen, die als Gefolgeerscheinungen des Wiederaufreissens von Erzgängen emporkommen und b) Minerallösungen auf Spalten, welche ältere Erzgänge oder andere Erzlagerstätten mit sulfidischer Erfüllung durchsetzen. Zum letzteren Falle gehören also die recht wichtigen *Gangkreuze.*

Da in beiden Fällen jüngere Schwermetalllösungen mit älteren reduzierenden Sulfiden zusammentreffen, können wir die Entstehung schwermetallreicher Sulfide erwarten, und es ist z. B. bekannt, dass sich die Gangkreuze häufig durch grossen Erzreichtum auszeichnen. Untersucht man aber die Erzführung ganzer Distrikte, deren Gänge sich durch Wiederaufreissen älterer Füllungen auszeichnen, genauer, so zeigen sich doch recht abweichende Erscheinungen. Auf unseren Siegerländer und Rheinischen Erzgängen besteht die erste Ausfüllung häufig aus Spateisen mit etwas Schwefelkies, der Spat wurde dann in einer späteren Periode der Gangbildung oft durch Quarz und beide Gangausfüllungen noch später durch Bleiglanz und Zinkblende verdrängt. Obgleich der Bleiglanz der rheinischen Gänge silberhaltig ist, konnte ich aber niemals um Schwefelkies Spuren von Zementations-Silbererzen finden, sondern nur gewöhnlichen Bleiglanz, wie er der primären Zone eigen ist.

Auf manchen Gängen des Rheinischen Schiefergebirges drangen als Gefolgeerscheinungen eines späteren Wiederaufreissens Kupferlösungen ein, es bildete sich Kupferkies, wie er häufig in der primären Zone auftritt, aber niemals fand ich die für die Zementationszone typischen Kupfer-Reicherze wie Buntkupfererz und Fahlerz, welche in der Zementationszone der rheinischen Gänge recht häufig durch deszendierende Lösungen gebildet auftreten.

Es müssen also *bei diesem Vorgange vom Zementationsprozess abweichende Bedingungen vorherrschen,* die noch der Aufklärung bedürfen.

Der zweite Fall der Erzbildung an sogenannten *Gangkreuzen* zeitigt mitunter zweifellos Erze, die denjenigen der Zementationszone nahestehen. Bekannt ist der Silberreichtum mancher Freiberger Gangkreuze und der Edelmetallvorrät von Goldgangkreuzen u. s. w. Aber auch hier haben die Erze einer seits nicht das Gepräge der f :e Zementationszone typischen und anderer seits finden sich in den Gangkreuzen bedeutende Anhäufungen von Erzen, die wir *nicht* als Leiterze der Zementationszone kennen wie z. B. Bleiglanz, Zinkblende, Uranpecherz u. s. w.

Ähnlich liegen die Verhältnisse in den Fällen, wo aus der Tiefe stammende Schwermetalllösungen ohne freien Sauerstoff mit anderen reduzierende Erze führenden nicht gangförmigen Lagerstätten zusammentreffen. Sehr lehrreiche Beispiele sind Nautanen in Lappland, Grasslitz-Klingental in Böhmen-Sachsen. Bei Nautanen drangen Kupferlösungen in Magneteisen führende Schichten ein und setzten Kupferkies ab, bei Grasslitz wirkten ältere Kiese, und zwar vorzugsweise Magnetkies, ausfällend auf jüngere Kupferlösungen, so dass sich ebenfalls Kupferkies in Trümern und als Imprägnation bildete. Auch hier entstand weder Buntkupferkies noch Kupferglanz durch diese aszendierenden Lösungen.

Ich komme damit zu den Vorkommen primären *Buntkupfererzes* und *Kupferglanzes* überhaupt. Es finden sich wohl in der Literatur Angaben über derartige Lagerstätten z. B. in Südnorwegen und Südafrika. Indessen kommt es sehr darauf an, von wem derartige Untersuchungen angestellt wurden; sie können nur als vollwertig gelten, wenn der betreffende Geologe die nötige Erfahrung auf dem Gebiete der Leiterze und ihrer Entstehung, einem der schwierigsten lagerstättenkundlichen, hat. Auch dann genügt nicht die makroskopische Prüfung, sondern es bedarf dringend der Dünnschliffuntersuchungen.

Bei allen von mir selbst untersuchten Vorkommen von Buntkupfererz und Kupferglanz, die mir Kollegen als vermutlich primär schilderten, konnte ich bisher mikroskopisch die sekundäre Entstehung nachweisen; ich stehe deshalb allen Behauptungen von dem primären Auftreten dieser reichen Kupfersulfide skeptisch gegenüber.

Die Ursache, warum aszendierende Lösungen im allgemeinen schwermetallärmere Sulfide bilden als deszendierende, muss in der Verschiedenheit der chemisch-geologischen Bedingungen bei der Erzbildung liegen; aszendierende Lösungen stehen gewöhnlich unter höherem Druck, haben höhere Temperatur und sind meist sehr verdünnt, deszendierende haben dagegen ungefähr die Durchschnittstemperatur des Brunnenwassers, stehen unter gewöhnlichem Druck und sind wegen der ständigen Berührung mit Schwermetallverbindungen relativ konzentriert. *Die drei letztgenannten Bedingungen müssen der Enststehung der schwermetallischen Sulfide günstiger sein als die erstgenannten.*

D. Wert der Dünnschliffuntersuchungen.

Aus den obigen Ausführungen geht die Bedeutung der Dünnschliffuntersuchungen für die Entscheidung derartiger nicht nur wissenschaftlich, sondern auch wirtschaftlich wichtigen Fragen hervor. Das Verdienst auf die Bedeutung des Mikroskops für die Lagerstättenforschung zuerst hingewiesen zu haben, gebührt unzweifelhaft **Beck**. In den letzten Jahren hat es immermehr Eingang gefunden und heute ist es ein unentbehrliches Hilfsmittel für die Lagerstättenkunde geworden. Vorläufig sind die sowohl bei auffallendem als bei durchfallendem Licht ausgeführten Untersuchungen noch wenig methodisch, die Mittel der Erkennung der einzelnen Erze sind nur einem verhältnismässig kleinen Kreise von Forschern bekannt. Schon jetzt lässt sich aber mit Sicherheit voraussehen, dass sich binnen kurzem eine *spezielle Erzpetrographie* herausbilden wird, die auf den Methoden der mikroskopischen Gesteins- und Metalluntersuchung weiterbaut.

A CONTRIBUTION TO THE METALLOGENY OF THE PHILIPPINE ISLANDS.

BY

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Ore-deposits throughout the world have been observed to show a relationship between certain types of mineral deposits and igneous activity,[1] and this observation seems to apply to the Philippines with special clearness. The importance of the Philippine ore-deposits has not yet become generally known, but the mining operations now in progress are certain to awaken a great deal of interest.

DISTRIBUTION OF ORE-DEPOSITS.

The Philippine Islands represent part of the Pacific ore-belt, which can be traced through the Malay Archipelago,[2] the Philippines, Formosa and Japan. The belt nearly encircles the Pacific ocean, and continues from Alaska through western United States, Mexico and South America. Everywhere this ore-belt follows lines of tectonic disturbances, generally indicated by uplift and profound igneous activity.

Igneous activity has existed in nearly all of the islands within the Philippines, hence, knowing the dependence of ore deposition upon such activity, the metals may be expected to be widely distributed. Such is the case, for quartz veins bearing gold, silver, copper, etc., have been found in nearly every island of considerable size. LINDGREN[3] has pointed out for the western United States the fact that "where the rocks lie horizontal and no disturbance had taken place, ore-deposits are rare, poor, or absent." In agreement with this, the ores are totally absent throughout the undisturbed sedimentary and tuff areas in the Philippines.

ORE-BELTS.

A group of ore-belts can be defined, extending through the central cordillera of northern Luzon, southward along Luzon, Marinduque, Masbate, Samar, Leyte, and the eastern half of Mindanao. This group may be divided into subsidiary belts which follow in trend and persistence the main cordilleras.

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[1] Compare VOGT, KEMP, LINDGREN, SPURR, DE LAUNAY, EMMONS, and others.
[2] DE LAUNAY, *Metallogénie Asiatique*.
[3] *The Mining Districts of the Western United States*, Bulletin 507, U. S. G. S., p. 7.

These ore-belts correspond in direction and length to the main tectonic lines which "in general run north and south, but minor departures from this direction are to be seen in the lines running through the islands of Palawan, Mindoro and those in the Sulu Group, the Zamboanga peninsula and Cebu."[1]

It is important to note that this list of tectonic lines departing from the general trend by the northeast direction comprise the regions where the least gold is known. The major northwest or north lines mark the gold belts rather than the minor northeast lines. In Aroroy, Masbate, where the two lines meet, valuable veins are found, which parallel the major northwest line. In Mindanao some minor tectonic lines show an east and west direction, and where these meet the major lines ore-deposits may occur. In general, there appears to be a relation between the greater tectonic features and the maximum ore deposition.

ORE-DEPOSITS AND IGNEOUS ACTIVITY.

The ore-deposits always are associated with igneous rocks and occur in veins in and around intrusive masses, forming "metallic aureoles"[2] so characteristic of mineral districts. Thus in the Paracale district the veins are found in granitic gneiss or the adjacent dioritic schist. In Aroroy[3] the veins are found mainly in andesites. In Benguet[4] the veins are found in andesite and to some extent in quartz-diorite. In the Mancayan-Suyoc[5] district the ores are found in diorite, andesite, and andesite breccia.

There is a total absence of ore-deposits in the sedimentaries, tuffs and lavas except where these are in proximity to intrusives.

In Benguet[6] some veins of the Major mine cut a small body of sedimentaries adjacent to andesite. SMITH[7] notes the occurrence of quartz veins in the schists of Mindanao at Misamis, Placer and near Zamboango. The area evidently has been subjected to great metamorphism, and the schists are of doubtful sedimentary origin. In the Angat iron region, DALBURG[8] found some magnetite ores at the contact of an igneous mass with limestone.

Great areas of sedimentaries are found devoid of deposits, evidencing, as pointed out by LINDGREN[9] for the western United States, the inability

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1 SMITH, *Geology of the Philippine Islands*; Phil. Jour. Sc., Vol. V, pp. 5, 308.

2 LINDGREN, Bulletin 507, U. S. G. S., p. 31

3 FERGUSON, *Aroroy, Masbate, Mineral District*; Phil. Jour. Sc., Sec. A.

4 EVELAND, *Baguio Mineral District*; Phil. Jour. Sc., Sec. A. (1907) pp. 4, 11, 207.
SMITH and EDDINGFIELD, *Baguio Mineral District*; Phil. Jour. Sc., Sec. A. (1911), Vol. VI, pp. 6, 425-429.

5 EVELAND, *Reconnaissance of the Mancayan-Suyoc Region*; Bull. 4. Mining Bureau, Manila, P.I.
EDDINGFIELD, Min. Res. Phil. Is., Div. of Mines, Bureau of Science.

6 SMITH and EDDINGFIELD, ibid., p. 432.

7 *Geologic Reconnaissance of Mindanao and Sulu*, part III; Phil. Jour. Sc., Sec. A, p. 6.

8 Assistant, Division of Mines, Bureau of Science, Manila, P.I.

9 Ibid., p. 8.

of atmospheric water, unassisted by igneous action, to form deposits. The intrusives of Paracale, Benguet and Mancayan-Suyoc are generally in contact with other igneous rocks, thus explaining the usual absence of veins in sedimentaries. However, where sedimentaries occur near the intrusives, veins may be expected to be found in them.

Large areas of lavas are known that are devoid of deposits, but the surface nature of these flows has obviously been unfavorable to ore formation. As noted by KEMP,[1] under surface conditions the magmatic waters and gases readily escape into the atmosphere before performing the work of mineral deposition. In addition, the quick cooling of the lava does not give sufficient time for the action of the heated circulating waters.

However, where lavas have been intruded by a later magma, such as in certain portions of the Aroroy field, deposits may be found in the lavas. In this case the later magma has afforded the conditions of time, temperature, and pressure necessary for fissuring and metallization.

The large mining districts appear to occur at loci of igneous activity. In Paracale, the veins occur within or adjacent to a small batholith. A batholith appears to underlie the central ore-belt extending from Benguet to Mancayan[2] and the veins are found in the batholith or in the rock intruded. The Aroroy district evidently has been the centre of great activity, as igneous rocks of plutonic, hypabyssal and extrusive types are found. Intrusion naturally is more intense than extrusion and the apparent dependence of the deposits upon intrusion rather than extrusion indicates that maximum igneous activity is a factor in the formation of the ores.

Rock types.—Apparently the type of magma has been influential in the formation of metalliferous areas. The above mentioned areas contain quartz-diorites, andesites or granites, that is, acid or intermediate types of rock. This association is known to be general for the ore-deposits of the Americas. A similar association obtains for Japan and Formosa, showing the uniformity of the Pacific metallogenic provinces. The basic rocks, such as basalts, are usually barren throughout these provinces, and the rule applies to the Philippines as well.

Magmatic relations.—The general magmatic sequence has been: (1) Intrusion of early andesites and diorites, (2) Intrusion of quartz-diorite or granite, (3) Vein formation, (4) Later intrusions and extrusions, chiefly of andesites and basalts. Intrusion has preceded and extrusion has followed the period of vein formation.

In Paracale the oldest rock is dioritic and later was intruded by granite. The veins did not immediately follow the solidification of the granite, for this rock was sheared to a gneiss before the differentiation of the andesitic dikes and the period of vein formation. Andesite and basalt flows are found south of the area.

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[1] *Role of the igneous rocks in the formation of veins;* Trans. Am. Inst. Min. Eng., Vol. XXXI, 1901.

[2] EVELAND, *Reconnaissance of the Mancayan-Suyoc Region*, p. 40.

In Aroroy, the oldest igneous rock is said to be intrusive quartz-diorite[1] and this was followed by intrusive and extrusive andesites. The andesites were followed by quartz veins, and these were followed by intrusions of leucite-tephrite, basalt and syenite. The period of maximum differentiation quickly followed the period of vein formation.

In Benguet, the oldest rock is an andesite which is intruded by quartz-diorite. The main period of vein formation appears to have followed this intrusion and may be nearly synchronous with the period of basalt differentiation that gave rise to the many dikes in the area. This point, however, is open to further field investigation. Andesite of later age followed the period of vein deposition, and a minor period of rock silicification took place. This silicification along fractures has continued with decreasing activity up to the present time.

In the Mancayan-Suyoc area, andesite similar to that found in Benguet is the oldest rock and this has been intruded by quartz-diorite. The period of vein formation followed the intrusion and preceded a flow of andesite. Additional mineralization is said to have taken place with the advent of this flow.[2]

Types of ore-deposits.—The ore-deposits belong nearly exclusively to the vein type. Contact-metamorphic and magmatic segregation deposits have not positively been identified.

In most cases the veins are simple in structure, though brecciated veins, fracture zones, etc., are not unknown. Disseminations of pyrite in the wall rocks usually accompany the veins, but the values are practically nil. Silicification and chloritization of the adjacent rocks are common.

Replacement and contact deposits are generally found along contacts of intrusives and limestones,[3] but such contacts appear to be rare in the Philippines, thus explaining the scarceness of deposits of these types.

Deposits along contacts of two igneous rocks are known to occur in several places but, as far as known, the rocks have shown no special precipitative action.

VEIN PHASES.

The veins may be divided into quartz and calcite phases, but every transition between the two types is known. In every district the number of quartz veins is much greater than that of calcite veins. Pegmatite veins are unknown.[4]

The quartz phase.—The quartz phase may be divided into the gold, the copper-gold and lead-zinc types, the relative positions of which with reference to the cooling magma are not fully known. Every variation between types is known.

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[1] FERGUSON, *Aroroy, Masbate, Mineral District*, p. 208.

[2] EVELAND, *Reconnaissance of the Mancayan-Suyoc District*, p. 48.

[3] LINDGREN, *Character and Genesis of Certain Contact Deposits*; Trans. Am. Inst. Min. Eng., Vol. XXXI, 1901, p. 226.

[4] Veins that possibly belong to the pegmatite type occur in Ilocos Norte.

In general the quartz phase shows gangue largely predominating over the sulphides, but in certain copper-gold types (Mancayan) and lead-zinc types (Marinduque, etc.) the sulphides predominate over the gangue. Such variations have been ascribed by SPURR[1] to the depth (temperature and pressure) at which the ores were deposited.

A distinct quartz phase appears to be shown by the occurrence of magnetite, hematite, pyrite and chalcopyrite in some quartz veins of the Angat iron region. The veins are not known to be gold-bearing. They evidently represent conditions of formation greatly differing from the gold-bearing veins in which magnetite is absent. Magnetite has been placed by EMMONS[2] in the list of minerals formed under deep-seated conditions, and the Angat veins possibly have formed under contact-metamorphic conditions.

SPURR[3] states that the free-goldbearing pyrite zone with a coarse quartz gangue will lie closer to the magmatic hearth than will the cupriferous pyrite zone. This agrees with the occurrences of the veins in Benguet, where the free-goldbearing pyrite ores are found in a zone close to the intrusion of quartz-diorite, while the cupriferous pyrite ores lie at a greater distance.

The calcite phase.—One of the most interesting features of the Philippine ore-deposits is the occurrence of gold-bearing calcite veins in proximity to quartz veins. The quartz veins contain little or no calcite; transition type veins contain calcite in alternate ribbons with quartz, or as irregular masses in the quartz, while the calcite veins contain massive crystalline calcite with little quartz. The great width and persistence of many of these veins, of all types, is highly characteristic. Widths of over six metres are not unusual. Unlike quartz, the data regarding calcite shows no evidence that it is differentiated from a magma. I infer that the calcium has been leached from the cooling igneous rock by carbonic waters, probably magmatic, and that the occurrence of calcite veins is probably a later phase of decreasing temperature and pressure. For instance, the field relations of calcite veins as seen on the Inca vein (Antamoke valley, Benguet) show the calcite phase to be later than the quartz phase. The 10-metre quartz vein on this property has been split open, and the fissure filled by a one-metre vein of calcite.

With a cooling magma, surface conditions of temperature and pressure would recede downward and produce the formation of calcite veins in proximity to the quartz veins which formed during the earlier period of greater temperature and pressure. This offers an attractive explanation of the occurrences of many adjacent calcite and quartz veins in Benguet, Mancayan-Suyoc and Aroroy. The proximity of these radically different types of veins should not be ascribed to different kinds of rocks through which the ascending solutions have passed, for the geology of these areas indicate that similar rocks occur in depth. The origin of the calcite can not be attributed to limestones, for limestones of earlier age than the veins are rare or absent and

[1] *A Theory of Ore-deposition*, Ec. Geol., Vol. XI, 1907.
[2] Ec. Geol., Vol. III, 1908, p. 620.
[3] Ibid., p. 770.

certainly cannot be expected to occur at depth in the batholiths from which the solutions evidently came.

VOGT has inferred that, under conditions of great temperature and pressure, carbon dioxide does not penetrate into the wall rocks. As this gas appears to be instrumental in the solution of calcium, a greater solution of calcium might be expected with lowering of temperature. Furthermore, as shown by ENGEL and VILLE[1] above 100 degrees C., lowering of temperature increases the solubility of carbonates. It would appear, then, that down to a certain point decrease of temperature favours the solution of calcium, and, consequently, that calcite veins would be typical of the later phases of rock-cooling. In addition, it is to be noted that calcite frequently is one of the last minerals to crystallize out of aqueous solution. It is to be noted that sulphides characterize quartz veins rather than calcite veins, in which sulphides are rare. This feature probably is the result of fumarolic variations in which hydrogen sulphide characterized the early magmatic emanations, while carbon dioxide characterized the later phases. This sequence is in harmony with some observations on volcanic emanations.[2]

Fissuring.—The direction of fissuring in each of the mineral districts of the Philippines appears to bear a relation either to the tectonic line of the area or to batholithic intrusion. In the case of Masbate district there are two sets of fissures: one set is parallel to the northwest tectonic line, and another set is parallel to the southeast tectonic line. In Mancayan-Suyoc district the trend of the mineralized zone is parallel to the tectonic line of the region. In Benguet the veins appear to be either parallel to or radially arranged with respect to the quartz-diorite batholith. The tectonic features of the region are somewhat complex and this is reflected in the varying strikes and dips of the veins. In Paracale the veins are not parallel to the tectonic line of the immediate region but strike northward at an angle of about 45° to it. However, their direction corresponds to the northern trend of most Philippine tectonic lines. The trend of the ore-zone in the nearby Nalesvetan district follows the tectonic line of the region.

The association of the veins with the deep-seated rocks at once suggests fissuring under conditions of considerable depth. As noted by LINDGREN,[3] veins formed at depth show structural and mineral characteristics distinct from those formed near the surface. The former are more persistent and regular. The Philippine veins in the majority of cases are clearly defined, very persistent and regular, hence evidencing deposition at depth. The large massive crystalline quartz veins so frequently seen in Paracale, Masbate and Benguet probably have formed at moderate depth, while the chalcedonic and drusy types of veins seen in several Masbate veins probably have formed under shallower conditions.

Some mineral associations.—As is so generally true in quartz veins, silver is found alloyed with gold. Bullion analyses have shown for the

[1] Compte Rendu, Vol. XCIII, p. 34.
[2] Owing to limited library facilities, additional data on this subject were not to hand.
[3] Bull. 507, U. S. G. S., 1912, p. 12.

Philippines a preponderance by weight of gold over silver, thus bringing the veins into the gold-silver class so widely developed in the western United States. The bullion from the various districts shows variation in fineness. The Paracale bullion has a fineness of about 850 gold with about 130 silver. Some copper and other metals are present.

The gol l occurs free (primary and secondary) and also associated with sulphides, principally pyrite, chalcopyrite and galena. Gold associated with sphalerite is unusual. Silver is associated particularly with galena, but galena in many veins contains little silver.

Tellurides are very inconspicuous in the deposits. Gold telluride from Mancayan-Suyoc has been isolated once only, and one or two samples of ore from the Tunlega mine gave a test for tellurium. Tellurides have been reported from Benguet. In order to investigate this further, 300 samples of typical Philippine ores from the most important mines were tested for tellurium, but none of the samples gave a test. It is evident, therefore, that if tellurides do occur they are of very minor importance. Deposits of the Cripple Creek type certainly are unknown. Likewise fluorides, which often accompany this type, are unknown. Bismuth ores are unknown. Barite, which is found in many American veins, has been observed only in the Mancayan-Suyoc area.

In addition to testing the ores for tellurium, the samples were tested for arsenic, which was found to be rare except in the arsenic-antimony-copper ores of Mancayan-Suyoc. Some gold and silver are found associated with these ores.

Silver ores are conspicuously rare in the Philippines, for the primary ores are low in silver and tropical conditions of excessive rainfall and rapid erosion together with the presence of calcite in many veins apparently have been unfavourable to the secondary enrichment of silver. It is to be noted that the silver ores appear to show a progressive decrease in importance from Japan through Formosa to the Philippines.

Mercury has been found in the Philippines, as would be expected from its occurrence elsewhere in the ore-belt encircling the Pacific. Likewise some platinum has been found in the alluvial deposits.

Lead-zinc ores occur in veins associated with andesite, but large deposits are unknown. This scarcity may be due to the absence of limestones in the mineralized areas, for lead ores frequently are associated with such rocks.

Tin is known to occur in the Malay States, Borneo and Japan, but has not been found in the Philippines. The occurrences in Borneo and Japan would suggest its presence. However, granitic rocks, with which tin is so generally associated, are found in very limited amount. Furthermore, the occurrences in other parts of the Orient are Mesozoic in age and intrusive rocks of this age are unknown in the Philippines. The minerals associated with tin, such as fluorine-bearing minerals, are unknown. The same may be said of pegmatite dikes.

Tests on a few ores have shown only slight radio-activity, apparently no greater than that shown by the enclosing rocks. In this connection a suggestion can be made, for it is known that decomposed or weathered products are low in radio-activity; and this fact may prove of value as a criterion for secondary enrichment—provided it can be shown that the secondary minerals are different in radio-activity from the primary minerals.

Metallogenic provinces.—The existence of a Pacific petrographic and metallogenic province has repeatedly been suggested. Metallogenic provinces of Tertiary age are known in Chili, Peru, Colombia, Mexico, California, Nevada, Utah, Colorado, Idaho, Unga Island, Japan, Sumatra, Celebes and Transylvania.

The Philippine deposits are certainly Tertiary, probably Miocene, and not only on the basis of age, but in rock types and mineralization, undoubtedly can be joined with this great group of provinces. However, structurally, the Philippine deposits should be classed with those deposits formed under intrusive rather than extrusive conditions.

THE PERSISTENCE OF ORE IN DEPTH.

BY

MALCOLM MACLAREN.

A study of the recent literature of ore-deposits inevitably forces the conclusion that workers in this branch of geology are endeavouring, in their zeal for the advancement of knowledge, to wrest from the scanty data available more than the simple facts warrant. Data that have been garnered from the examination of a given metalliferous deposit, and that have a real value when applied to the construction of a sound theory of deposition for that metal alone, have been transferred to stay and brace the tottering structure built for another metal, with which the first may eventually prove to have only the slightest genetic affinity, however closely allied they may appear to be to-day. When all the known facts concerning the deposition of any one metal have been collected, collated and analyzed, then, and not until then, may comparison be made with the data of another metal similarly treated. Some metals—e.g., tin and copper, clearly lie so far apart genetically that no confusion of data has resulted, but the general impression appears to be that the data concerning the ores of other metals are interchangeable. They may often indeed be so, but the time has not yet arrived when transfers may be made with safety. For this reason, therefore, the ores of one metal only, viz., gold, are considered in the following brief review.

As a preliminary, a definition of "depth" appears to be necessary. Here it is assumed to cover only the (presumably) primary ore that lies beneath the zones of secondary enrichment (oxide and sulphide) and to extend for a limited depth, say 1,000 feet, below the bottom of the deepest mines, or 6,000 feet in all. To take the enquiry deeper is to enter the barren zone of speculation. The combined depths of the oxide and sulphide zones of enrichment may vary with climatic conditions from a few feet to a few hundred feet. Ordinarily, below 500 feet we are, for most gold ore-bodies, in the primary zone. A word may be said in regard to the use of the term "primary ore." It comprises that ore for which we know no prior state of combination and no former locus in space. In this review then, depth is understood to be a zone extending downwards from 500 feet to 6,000 feet below the earth's surface. The ore in this zone may be assumed to have been deposited during a single short geological era, and to owe nothing to accretions of a widely separated and later period. It is probable that the irruption of auriferous solutions was normally paroxysmal in character and, indeed, was comparable to volcanic eruptions of the present day. Only those fissures and channels that were open at the geological moment, so to speak, were filled with ore.

An assumption of this nature may help to explain the vertical variations in the tenor of the ore in the primary zone, where in many mines, horizontal bands of richer and poorer ore alternate. These alternations conceivably represent the varying horizons at which successive upward pulsations of metalliferous solutions either became sufficiently cool to be deposited or met with fluid agents of deposition.

I have elsewhere[1] attempted to show that the gold deposits of the world fall naturally into well-defined auriferous groups, the members of each group, though widely separated in space, being closely allied in genesis, in character, and in geological age. One of the most important distinguishing characters of the several groups is persistence (or otherwise) of ore in depth. The classification adopted must therefore be outlined.

TABLE I.

(a) Arising as the end-product (generally following albite-porphyry) of diabasic magmatic differentiation series intrusive into schists.	Pre-Cambrian	Western Australia (Kalgoorlie, etc.), India (Kolar, Hutti, and Dharwar) Rhodesia, Transvaal (Witwatersrand, Pilgrim's Rest, Barberton), Brazil (?), Guianas, Appalachian fields, Eastern Canada (Porcupine, etc.).
(b) Arising as the end-product of granodioritic intrusions.	? Permo-Carboniferous to Post-Jurassic	(a) Urals. (b) Eastern Australia and Tasmania. (c) Western North America (California, Oregon, and Alaska).
(c) Associated with andesite volcanic eruptions.	Middle Tertiary	Northern Chili, Peru, Colombia, Mexico, California (Bodie), Nevada, Utah, Colorado, Unalaska, Japan, Sumatra, Celebes, New Zealand, Transylvania.

The above table varies slightly from that originally adopted, but four years' further field experience has enabled me to abolish the former tentative subdivision of the Pre-Cambrian deposits and has given a much clearer view of the general sequence of events leading up to auriferous deposition in that age. These groups, therefore, contain all the important gold deposits of the world. Two of these, viz., the Pre-Cambrian and the Tertiary are extremely well defined; the third, including all apparently dependent granodioritic magmas, is still somewhat indefinite and will certainly be modified with increase of knowledge. Probably, when the exact age of its auriferous impregnation is known, the Ural chain of deposits will be brought into close accordance with the Eastern Australian, while the Californian (Mother Lode, etc.) occurrences may eventually be transferred to the Tertiary andesitic group, with which they are indeed orographically closely connected.

In any consideration of the question of the persistence of gold ore in depth the foregoing divisions must be kept closely in mind, since the recurrence of evidence of the complete dependence of gold deposits on geological condi-

[1] MACLAREN, *Gold*, London, 1908, pp. 42-75.

tions, both for deposition and for extension, lateral and vertical, is certainly the most salient feature arising from the study of the goldfields of the world.

It will probably be most convenient to first consider the younger goldfields. These are the andesitic fields that have furnished some of the greatest bonanzas that have been known. Their petrological range is from pyroxene-andesite to quartz-trachyte, and occasionally to rhyolite, all apparently the differentiation members of a dacitic magma. Their geological range is from Eocene to Pliocene with a special development in the Oligocene and Miocene. With one notable exception they follow very closely and are confined to the so-called "Pacific Circle of Fire," with which line of volcanic activity they have clearly a very close genetic connection. The outstanding feature of gold deposition in this group is its modernity and its consequent intimate association with existing volcanic phenomena. The geographical exception is the Transylvanian goldfield of Hungary, the andesites of which were erupted during the Aquitanian stage, and along lines of crustal weakness initiated in the Oligocene and indicated at the present day by the active volcanoes of the Mediterranean.

Auriferous deposition in this group has probably been closely associated with solfataric action. MACLAURIN has indeed shown that the hot springs of the solfataric region of New Zealand at the present day bring to the surface and deposit notable quantities of gold and silver in the siliceous sinter that forms on the edges of the boiling springs. A similar deposit is recorded from near the De Lamar mine, Idaho. The New Zealand hydrothermal region is on the same line of crustal weakness as the goldfields of the Hauraki peninsula. On it, only 40 miles away from Rotorua, is the famous Waihi mine, until three years ago one of the greatest of the world's gold mines. The chalcedonic character of the siliceous filling of the veins of many andesite fields also appears to point to a deposition from hot waters. In andesitic and allied rocks in the neighbourhood of auriferous veins "propylitization" is universal. In this facies of the original andesitic rock the feldspars and ferro-magnesian silicates have been converted to quartz, sericite, calcite, epidote, chlorite, serpentine and pyrite.

The outstanding feature of auriferous ore-bodies in andesitic fields is their general irregularity, both in form and in tenor. The great persistent fault fissures so often found in older and deeper seated rocks are unknown, or, at any rate, have not served as loci of deposition. There is nothing in any andesitic field comparable, e.g., with the Mother Lode fracture of California.

It is, of course, conceivable that strong fault fissures could readily have been formed, but it is improbable that in any active volcanic and solfataric region, such fault fissures would remain open for any length when large quantities of cementing igneous and aqueous matter were being brought to the surface along the assumed line of weakness. The Comstock Lode with a total length of two and a half miles is probably the longest fault-fissure lode of economic importance in the andesitic fields. Normally the fissures of andesitic fields appear to be local tension fractures due sometimes to cooling and sometimes to minor local movements. They are therefore limited both in linear and in vertical extension, falling into the group of "gash veins" of an old nomenclature. When two or more local series of fractures intersect, the "stockwerk" so characteristic of many New Zealand and Transylvanian areas results.

Where the veins of the stockwerk are sufficiently close together a great bonanza may result, as in the case of the Shotover and Caledonian mines, Thames, New Zealand. The original irregularity of the andesitic fissures is greatly accentuated by the selective action of auriferous solutions that replace the fissure walls with ore.

No andesitic field has as yet carried its bonanzas to great depths. By far the deepest is the Comstock, where shafts were sunk to 3,300 feet, but though ore was found erratically distributed through the lower workings, it was in nowise comparable to the great bonanzas that occurred between the 1,000 ft. and 1,800 ft. levels. Only a very few mines in andesitic regions have carried rich ore below 1,000 feet, and the characteristic feature of even these is uncertainty of persistence in depth. For the lack of persistence a definite reason may very often be given, viz., the change along the downward course of the lode from dacite or andesite to the underlying basement rock, or, in rarer cases, to a member of the andesitic differentiation series unfavourable to gold deposition. Often the mere approach to the basement rock connotes impoverishment of lodes. Instances are numerous, e.g., in New Zealand (at Coromandel and Thames), in Colorado (at Cripple Creek and Telluride), in Transylvania (at Vulkoj, Korabia, and Nagyag); but there are many lodes that persist in a homogeneous rock, which may be either a member of the andesitic differentiation series or may form a member of the basement complex through which andesites have burst, and that nevertheless, show a marked diminution in value at comparatively shallow depths, often less than 500 feet. For some of these impoverishments a physical cause may be advanced, viz., approach to the bottom of the zone of erosion; but for others, indeed for the great majority, no such explanation is possible. For example, the Comstock fissure is well-defined as far as it has been followed downward. The great Martha lode-fissure (Waihi) persists as strongly as ever below 1,000 feet, but whereas above that level the gangue was mainly quartz, below it the matrix is calcite. The Martha Lode appears to have been originally wholly a calcite lode that was attacked by solfataric waters above 1,000 feet, silica with accompanying gold almost completely replacing the calcite. Either, then, 1,000 feet below the surface marks the horizon at which solfataric waters become active agents of solution and deposition or, and more probably, the percolating waters had no access to a zone of the lode immediately below the 1,000 foot level. Whether at greater depths they used the lode-fissure as a channel and replaced its calcite gangue future exploration alone can show. Here, as has so often been the case, the solution of the question of the persistence of ore in depth depends on economic considerations.

The impoverishment of the veins of the andesitic gold fields in depth is a feature so universal that a general cause for diminution in value must be sought. I have attempted to show elsewhere that the probable form in which gold travels in solution, in depth at least, is not as the chloride, but as an alkaline auro-sulphide, and that pyrite and other sulphides are not the natural precipitants in depth but that precipitation may be due to a more general cause, as cooling of uprising solutions.[1] Recently LENHER,[2] to whose laboratory researches field workers are deeply indebted, has shown that the alkaline sulphide solutions are highly efficient carriers of gold, that pyrite has no effect on their contained gold and that their gold is readily precipitated by acid waters or by exposure to oxidation. Both these agents may reasonably be assumed to operate only near the surface, especially in volcanic regions. MACLAURIN found that the waters of the acid lake on White island, New Zealand, contained 5.47 per cent. of free hydrochloric acid. Little proof of the existence and wide distribution of acid waters at the earth's surface in solfataric regions is, however, necessary. While the former cause probably operates directly in andesitic regions proper, deposition of gold in the numerous cases in Colorado, Nevada, Transylvania, etc., in which the gold-quartz veins lie in older sedimentary or plutonic rocks, is more likely to be due to oxidizing waters, the influence of which naturally reaches only a short distance beneath the earth's surface.

Recognition of the irregularity and lack of persistence of auriferous ore-bodies in andesitic fields is of prime importance to the mining engineer. For such ore-bodies not a single ton of ore more than has been actually proved may be assumed.

The second group of the classification already outlined includes those goldfields that are apparently genetically connected with granodioritic or closely allied magmas and that occur as a product of their differentiation This group contains three geographical provinces, viz., Eastern Australia, California, Alaska, and the Urals. For the purpose of the present paper they may also be divided simply into (a) lodes in granodiorite and allied rock and (b) lodes in the sedimentary complex through which the granodiorite is intrusive. The relations of the former are simple. Those of the latter are greatly complicated, from the present point of view, by changes in tenor likely to take place when lodes pass in depth from one member of the complex to another.

The deposits of the Eastern Cordillera of Australia are initially dependent on great granodioritic intrusions that have taken place along an axial line of earth folding. Gold-quartz veins may occur either in the igneous rock itself or in the sedimentary strata overlying or adjacent. The habitus of the gold deposits in the north is, in the main, in the granitoid rock; while in the south gold-quartz veins are generally found in sedimentary rocks. Important exceptions to both rules occur and are of special value as evidences of the general genetic connection between the gold deposits of the north and the south, respectively. The general age of the plutonic intrusion is probably late

[1] MACLAREN, *Gold*, London, 1908, pp. 38, 78, etc.
[2] Econ. Geol., Vol. VII, 1912, p. 744.

Permo-Carboniferous. All adjacent strata of great age may therefore carry auriferous veins. Charters Towers in North Queensland, with a production of nearly £29,000,000, is the most important field in the granitoid rocks. Its igneous complex comprises rocks ranging from grey hornblende-granite to tonalite, the latter being the predominant rock. The two principal lodes are the Brilliant and the Day Dawn, which have been worked to depths of 2,500 to 2,700 feet. On the whole, the ore has shown a gradual though small diminution of tenor in depth. Similar fields are those of Croydon (Queensland), and Wyalong (New South Wales); neither furnish any evidence bearing on the point in question.

Considering the number and great importance of the goldfields of Eastern Australia developed in sedimentary rocks the light thrown by them on the general question of persistence of ore-bodies in depth is singularly little. Certainly some, as Gympie (Queensland) and Ballarat (Victoria), depend for auriferous deposition on the intersection of lodes or quartz veins and graphitic bands in sedimentary strata, a condition which is not necessarily recurrent at depth. Others, including the majority of the important Victorian fields and the Hargraves field in New South Wales, are developed in tension fractures between unlike beds at the crests of anticlines forming, e.g., the famous "saddle reefs" of Bendigo and Castlemaine. In these fields saddle reefs are successively met with in depth when sinking on an anticlinal axis, so that a condition ensues very different from that met with when considering the filling in depth of a single continuous fissure. But the experience gained on these formations all tends to show that the lower saddles are not nearly so rich or so large as those above. At Bendigo mining operations were carried to 4,614 feet below the surface in the New Chum mine, but it is very probable that, taken as a whole, work on the Bendigo field below 2,500 feet has not been profitable. Certainly the tenor of the ore has decreased in depth.

In the California-Alaska belt of gold lodes, which are apparently dependent on granodiorite magmas, the various Mother Lode mines and the Alaska-Treadwell group in south-eastern Alaska are the most important. The latter are still shallow and are of no help in the present discussion. Many of the Mother Lode mines, especially in Amador county, are nearly 2,000 feet deep and some, as Kennedy (3,650 feet), Gwin, (2,650 feet), and South Eureka (2,850 feet), have reached much greater depths.

The Mother Lode is a fissure zone that may be traced from Bridgeport in Mariposa county to near the northern boundary of Eldorado county, a distance of 120 miles. In many places it is a solid lode 100 feet wide, but often it is merely a shattered zone in which numerous quartz stringers are developed. It is undoubtedly due to major faulting developed along a line parallel with the axis of the Sierras during the uplift of those mountains. The faulting has selected the softest beds (Mariposa slates) of the sediments and has uplifted them for great distances.

So far as my three months' examination of the Mother Lode permitted I have not been able to make out any appreciable diminution in tenor in depth.

Many mines have certainly "bottomed" the ore in given fissures at depths less than 2,000 feet, but it often happens that two or more parallel lodes occur within the Mariposa slates and that when one becomes barren a hanging-wall or footwall lode may carry ore to much greater depths. In few auriferous regions is crosscutting from wall to wall of the lode-channel more necessary; in few has less been done than along the Mother Lode. The mines of Angels Camp are often instanced as evidence of the occasional non-persistence of Mother Lode mines in depth, but, assuming for the moment that no ore occurs there in depth, their evidence cannot be admitted against Mother Lode mines. They are, it is true, on the line of the Mother Lode fissure-zone, but, from the Hardenburg mine south of Jackson to near the Rawhide mine south of Tuttletown, the Mother Lode fissure zone, keeping a straight course, leaves the Mariposa slates, which curve to the west through the Gwin mine and run parallel for many miles before rejoining the fissure zone south of Stanislaus river. One of the factors (viz., the presence of carbonaceous slates) that makes Mother Lode mine is therefore lacking at Angels Camp.

While, therefore, any given fissure of the Mother Lode series may cease to yield ore in depth it is probable that ore will be found at greater depth in another adjacent member. Finally, when broadly considered, the Mother Lode may, with unchanged geological conditions, be expected to carry ore with undiminished tenor to and perhaps beyond the limit of "depth" set forth in this paper.

No evidence of value is to be derived from a study of the gold veins of the Urals. They are nearly all small and irregular and no deep mining has been done on them.

Reviewing the scanty evidence furnished by the granodioritic group, we find for Eastern Australia a gradual though small diminution of the tenor of ore-bodies in depth, while on the Mother Lode all the evidence points towards a general persistence in depth for typical Mother Lode mines. A mining engineer, dealing with the future of these mines, would not, therefore, unless he had evidence of an approaching change in geological conditions, be justified in disregarding all ore except that "in sight": some might be expected to occur below the deepest present explorations, and such ore should always be taken into economic consideration.

The third group of the classification includes all Pre-Cambrian goldfields and comprises the most important now being worked. These lie in two geographical areas, one on the borders of the Indian ocean, ranging from Western Australia through Southern India and Egypt to Rhodesia and the Transvaal, and the other along the eastern side of America from Eastern Canada through the Appalachian chain and the Guianas to Brazil and Tierra del Fuego. The former is a very well-defined group of goldfields that, though geographically widely separated, present so many points of similarity that a geological description of the various rocks and of their internal relations in any given region would serve, with the mere change of place names, for any other region of the group. The members are consequently believed to form a single petrological and metallogenetic province, for which the appellation Erythræan[1] has been suggested.

A typical Pre-Cambrian field is that of Kalgoorlie in Western Australia. Its total gold production has been more than forty millions sterling. It has been closely studied by the writer and throws considerable light on the general question of auriferous deposition in Pre-Cambrian rocks and on the persistence of ore in depth in those rocks. Briefly, the area is one of ancient schists (mainly calc-schist) through which a quartz-dolerite magma with its differentiation products has intruded. The differentiation sequence appears to have been quartz-dolerite (quartz-diabase), followed first by members as basic as peridotite and then by more acid segregations ranging through porphyrite to final albite-porphyry, the last being often intrusive through the quartz-dolerite. Auriferous impregnation followed closely on the intrusion of the albite-porphyry. Rich lodes have been developed only in shear-zones in a broad dyke of quartz-dolerite, the shear-zones being barren when they pass

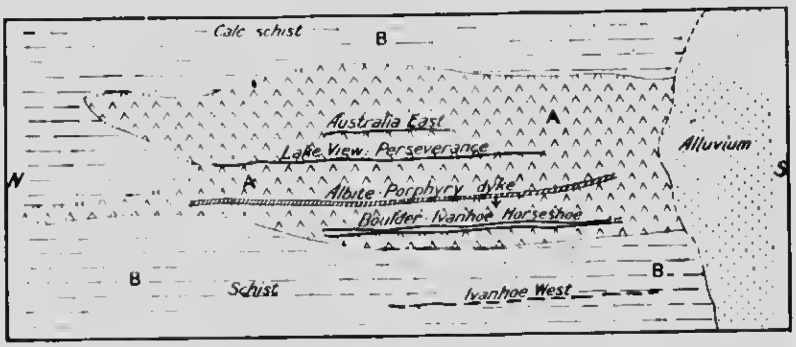

FIG. 1. Diagrammatic plan of productive area of Kalgoorlie, Western Australia, showing principal lode-channels.
AA. Quartz-dolerite dyke intrusive through calc-schists (BB).

in depth or in linear extension out of the quartz-dolerite. Since the shear-zones are, when considered over depths of 3,000 feet, approximately vertical, and the quartz-dolerite dyke which is parallel to the strike of the shear-zones dips west at 65°, the shear-zones pass in depth out of the dyke, the eastern shear-zones with their contained lodes reaching barren ground sooner than the western (see plan and section). Kalgoorlie, therefore, well illustrates an outstanding feature of all goldfields, except indeed some in the Tertiary group, viz., that non-persistence of ore in depth is a function not of depth but of geological structure. In Kalgoorlie three well-defined parallel shear-zones may be made out. Taken severally, and having regard to the depth factor alone, they show (a) non-persistence of ore in depth (Australia East and Lake View-Perseverance lodes), (b) persistence of ore in depth (Great Boulder and Ivanhoe-Horseshoe lodes), and (c) a probable enrichment in depth (Ivanhoe West lode). Generalizations based on the depth factor alone

[1] MACLAREN, Trans. Inst. Min. Met., Vol. XVI, 1907, p. 15.

when geological conditions are unknown are misleading. Rickard,[1] for example, has relied on the evidence furnished by the failure in depth of the eastern lodes and an impoverishment in the Ivanhoe mine at 2,500 feet to support a general theory of impoverishment in depth. Garrison[2] also quotes the Ivanhoe impoverishment as possible evidence of non-persistence in depth. The Ivanhoe impoverishment does take place, but it is local and is due to the fact that the vertical Ivanhoe lode here passes through a thin albite-porphyry dyke dipping west about 65°. The great Boulder lode passed through the same dyke with local impoverishment at 2,200 feet. When, however, the latter lode was encountered beneath the albite-porphyry dyke it proved as rich as in upper levels, and the same result may reasonably

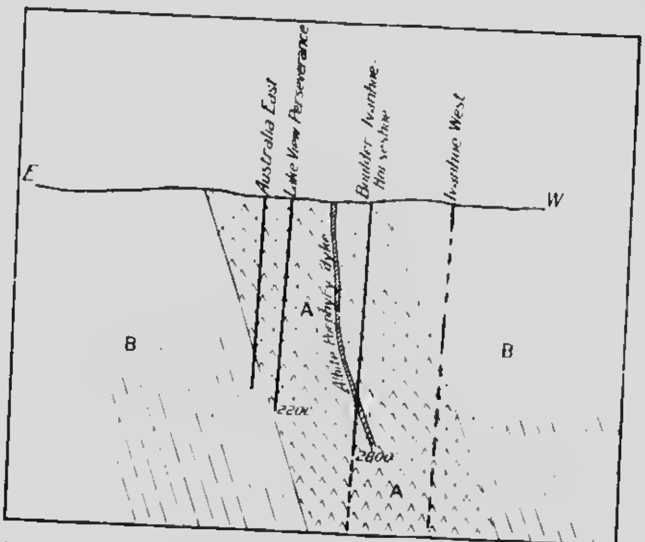

Fig. 2. Diagrammatic section through Kalgoorlie auriferous area, showing vertical lode-channels.
AA. Quartz-dolerite; BB schists (calc-schists, etc.).

be expected in Ivanhoe deeper levels. So far, then, as the evidence furnished by Kalgoorlie goes, it indicates that, so long as its lodes remain in quartz-dolerite, so long will they furnish ore equal in tenor to that found from the 500 to the 2,000 ft. levels. The Horseshoe-Ivanhoe group of lodes may therefore be expected to carry ore to the 5,500 ft. level, provided always that the quartz-dolerite dyke persists, does not flatten in dip, and is not thrown westward in depth by westerly dipping reversed faulting.

Archæan strata, from the vicissitudes to which they have been subjected in the course of long geological ages, are normally much folded and disturbed, while lode-fissures in them are nearly vertical. It is a fundamental axiom

[1] Min. Sci. Press, Aug. 31, 1912, p. 264.
[2] Loc. cit., Nov. 30, 1912, p. 701.

in these older deposits that the nature of the lode wall exercises a vital influence on the richness and sometimes on the mineral character of the ore-body. Hence it rarely happens that a great depth is reached before the lode, worked from the outcrop downward, has passed out of the favourable rock. A notable exception is the Champion Reef of the Kolar goldfield, southern India, probably the richest single gold lode ever worked. From 3,200 to 3,800 feet ore as rich as any obtained in the upper levels is now being worked and ore may be expected to persist in this fissure as long as it remains in the favourable hornblende-schist.

The greatest goldfield of the world, viz., the Witwatersrand, responsible for 37 per cent. of the world's gold production, is a Pre-Cambrian goldfield, but the criteria of ordinary Pre-Cambrian fields do not apply to it. Its deposits lie in sedimentary quartzites and conglomerates and are undoubtedly decreasing in tenor in depth. Having regard to all the geological conditions surrounding auriferous deposition on this field, it may be assumed that its gold was deposited relatively near the then existing surface and that deposition was due either to cooling on approach to the surface or to admixture with oxidizing waters, which in basin-shaped sedimentary areas as those of the Witwatersrand, we know from analogy with artesian areas, may reach to depths of several thousand feet. The surface of most Pre-Cambrian goldfields, on the other hand, has been subjected to erosion during a large portion of geological time, and the locus of gold deposition though now comparatively near the surface, was at the period of impregnation many thousands of feet below the then existing surface and beyond the reach of oxidizing waters, perhaps even beyond the influence of thermal changes.

SUMMARY.

Where auriferous ore-bodies have been deposited by the influence of meteoric oxidizing waters or by cooling on approach to the earth's surface, they may reasonably be expected to diminish in tenor with increasing depth and finally to disappear. The deposits to which this generalization appear to apply are those of the Tertiary andesitic group. Even for many of these, non-persistence of ore is more often a function of geological structure than of increase in depth. For all other deposits, and especially for those of the Pre-Cambrian group, ore formed in strong well-defined fissures may be expected to persist unchanged (apart from local horizontal variations) in "depth", provided the rock of the lode walls is homogeneous and that the ore-bearing fissure does not pass out of that rock. In all these, therefore, geological structure and not "depth" is the factor controlling the persistence of ore. "Depth" exercises only an indirect control, inasmuch as the greater the depth the more is the likelihood of geological change.

DISCUSSION SUR L'INFLUENCE DE LA PROFONDEUR SUR LA NATURE DES GISEMENTS METALLIFÈRES.

S. TABER (Columbia): Professor KEMP has referred in his paper to the moderate depth at which large open spaces, suitable for the reception of ores, can be formed. Recent studies made in the gold belt of the southern Appalachians indicate that veins, other than replacement deposits, m[illegible]e formed at depths where appreciable openings would be closed by rock pressure. I[illegible]t region a thickness of perhaps 15,000 or 20,000 feet of overlying material has been [illegible]moved since the formation of the veins. There is conclusive evidence that certain gold veins in Virginia were not deposited in preëxisting fissures but that their walls were forced apart by pressure when the veins were formed.* Two hypotheses have been advanced to account for the existence of such pressure: (1) the ore-bearing solutions were forced in from below under sufficient pressure to push the walls apart, and (2) the pressure was exerted by the crystallization and growth of the vein-forming minerals. I believe that the evidence is strongly in favour of the latter hypothesis, and that these veins are due to the force exerted by growing crystals.

W. LINDGREN (Boston): I am much interested in Dr. TABER's remarks, though, as I have not read the paper, I cannot discuss the subject in detail. However, I would like to say that the theory of vein formation by the force of growing crystals must take into consideration the circumstance that the force necessary to open the walls acts in one direction and that the resulting structure cannot fail to show this in a platy development of the quartz crystals. The veins to which Dr. TABER refers are characterized by coarsely granular, irregular structure, and show no evidence of development under one-sided pressure. If, on the other hand, the fissure were opened by the pressure of the solution, as in the case of a pegmatite vein or a dike, the crystals could develop without interference.

Dr. TABER: I did not intend that my statements concerning the force of crystallization as a factor in the formation of veins should be applied to the formation of all veins or of pegmatite dikes, but only to the veins referred to in Virginia. However, I have seen some small lenticular pegmatite veins occurring in schists which may be explained by this process.

G. F. BECKER (Washington), called attention to the separation of slate laminæ on the mother lode of California by the linear force of growing quartz crystals.

F. L. RANSOME (Washington): Although it has been demonstrated that growing crystals do exert measurable pressure against confining walls, I doubt if such a force would be great enough to form veins at great depth. In addition to the difficulties suggested by Professor LINDGREN, I wish to point out that in considering the possibility of fissures forming at great depth, we must bear in mind that the solutions which filled the openings were under approximately the same pressure as the rocks. This rather obvious relation is sometimes overlooked by those who attempt to place a limiting depth to the formation of so-called open fissures.

A. C. LAWSON (Berkeley), cited a case in which salt water, having been left to evaporate in a glazed earthenware salad bowl, passed through the wall of the bowl and formed a vein on the outer side between the earthenware and the glaze. The vein was about ⅛ inch thick and had a columnar structure normal to the walls. In crystallizing, the salt had lifted the outer glaze uniformly over areas, some of which were two square inches in extent. There the force of crystallization had clearly opened the walls of the vein and the only question was as to the extent to which the process applied in the veins of the earth's crust. It was doubtless of limited application but well worthy of recognition as a factor in vein formation. The speaker also described veins of columnar quartz in stretched boulder conglomerates that filled transverse fissures, up to more than an inch in width, in the boulders. There the columnar structure was induced by the slow opening of the gashes in the boulders as

*STEPHEN TABER, *Geology of the Gold Belt in the James River Basin, Virginia;* Virginia Geological Survey, Bull. II, 1913, pp. 222-231.

the rock was stretched, the shearing being confined to the matrix of the conglomerate.

W. LINDGREN: The subject of the migration of gold in deposits is fascinating and difficult. First as to placers, I cannot find any evidence that the solution and redeposition of gold in such occurrence has ever been of any economic importance, though I have seen instances proving that such redeposition may take place.

As to veins, gold is no doubt transported and deposited under some circumstances, particularly in veins rich in sulphides or in manganese. But this process certainly is slow and gold is not carried far. I have in mind two deposits, one with coarse gold, the other with extremely fine gold, in neither of which there is the slightest evidence of transportation of gold. I would like to ask Professor EMMONS what, in his experience, the greatest vertical distance is over which gold in a vein may be carried down and redeposited.

J. F. KEMP (New York): Professor EMMONS' results are of exceptional interest and importance. They bring up the crucial point of this discussion. The depth, however, to which the descending solutions may carry new contributions of metals derived from the overlying parts is all important in its bearing on the behaviour of ore in depth. Even if we can produce by experiment the ruby silver ores, are they impossible as original precipitates from uprising solutions? Can we conceive of their descent through standing ground-water to such depths as 2,000, 3,000, or 5,000 feet?

T. READ (New York): Chemical experience indicates that surprisingly important and extensive effects may be and are produced by very small quantities of active substances, the presence of which may be overlooked except in the most careful chemical analysis. For example, the apparent effect of pyrrhotite upon a solution may really be due to some substance present in the pyrrhotite in minute amount, just as in other chemical reactions a small amount of catalytic substance is known to produce remarkable effects. Also, chemical study in the laboratory of the processes of ore formation necessarily requires the greatest care, both in the preparation of the solutions employed and in the analyses of the minerals. Hence this method is one that does not recommend itself to every student of geology, but only to those who, like Professor EMMONS, are equipped to perform with extreme care the analyses upon which accurate deductions are to be based. Even with such care extreme caution must be exercised in drawing inferences from the laboratory phenomena observed. VAN 'T HOFF and his students have made numerous careful studies which strikingly illustrate the great complexity of the results obtained with comparatively simple groups of salts under comparatively narrow ranges of variation of temperature. In the case of ore-forming solutions much greater ranges of temperature and pressure are involved, while the substances which may take part in the reactions are so numerous as to make the problem one of great difficulty. Nevertheless, by proceeding from the more simple to the more complex, results of great value will undoubtedly be obtained in this way.

J. A. UDDEN (Austin): In reading current literature bearing on the level of secondary enrichment of mineral deposits it has seemed to me that the present ground-water-level in any particular locality is too often assumed to represent this level at the time of the enrichment. But as ore-deposits have been formed at different times in the past, and as progressive changes of level have been general, it is evident that such is not necessarily the case.

H. V. WINCHELL (Minneapolis): I would like to emphasize the importance of experimental work on the genesis of secondary sulphides. In the United States secondary ores, especially those of copper, are more important economically than many, particularly the European writers, have seemed to appreciate.

There is also a very intimate relation between secondary sulphide enrichment and the geographic distribution of ore-deposits. The climatic and topographic conditions have much bearing upon ore deposition; and it may be stated as a general truth that secondary sulphides are much more abundant and extend to far greater depths in dry regions of moderately high latitudes than they do farther north.

A. C. LAWSON called attention to the rôle which the process known as secondary sulphide enrichment played in the primary concentration of ore-bodies. Igneous rocks containing pyrite are commonly decomposed in the arid region by sulphuric-acid attack of the silicates, and their chemical decomposition may proceed to depths of hundreds of feet, involving a downward migration of free silica and any metals which the rock may contain. These are deposited in favourable situations determined by faults, shear-zones, gouges, etc. This is the most probable origin of many of the shallow ore-bodies in the

Tertiary igneous rocks of Nevada. The process is not merely additive to a pre-existent ore but it originates the ore-body.

On the other hand, flat-lying, tabular ore-bodies on exposure to oxidation yield descending solutions which become diffused through the deeper rock and effect a pauperization of the ore-body without concentration in depth. Thus the process which we call secondary enrichment is often misnamed. The present designation of the process obscures the generality of its operation and a more comprehensive name should be given to it to bring out its geological importance.

S. PAIGE (Washington): The assumption made by Dr. FERMOR that the reactions mentioned in his paper are reversible is an important one. It is probable that conditions of pressure and temperature at the beginning and at the end of the process were different. But the assumption that silicates are readily formed in the presence of CO_2, and as easily broken down by the CO_2, needs experimental support.

H. V. WINCHELL: In my former remarks I implied that the Germans are slow in adopting the theory of secondary sulphide enrichment. But having heard Dr. KRUSCH's paper, I wish to retract this statement. Once having taken it up they appear to have carried it through and beneath the ground-water, and have attributed to it much deeper ore deposition than we have suggested for it in this country.

A. C. LANE (Boston): The circulation of solutions below ground-water is promoted not only by differences of specific gravity and of course by differences of hydrostatic head in inverted siphons, but also by the fact that hot water and gas contract more in cooling than rocks do, so that in vesicular or porous rocks (amygdaloids) water can be drawn down by imbibition.

A. E. KITSON (London): In the yellow and gray clay-slates immediately underlying the rich auriferous gravels of the Chiltern Valley Deep lead in northeastern Victoria, Australia, gold occurs as a thin film and in places also as small crystals, on the cleavage planes of the rocks. I have seen some good examples of these which were in the possession of Mr. E. J. DUNN, late Director of the Geological Survey, Victoria.

In Kanowna district, Western Australia, the numerous joints of the decomposed igneous rock (porphyry?) underlying the detrital deposits of the Kanowna "deep lead" were coated with an extremely thin film of gold. At the time of my visit in 1905, a mine working in this rock had proved the gold for some 30 feet below the bottom of the lead. The yield of gold from the upper portions of the rock was from 10 to 12 dwt. to the ton, but there was a decrease with depth and I understand that deeper sinking proved the rock to be unprofitable. Where I saw it every joint was covered with a very thin film of gold, but none was visible in the rock itself, and no quartz veins were noticed. It has been contended that this Kanowna deposit is not a true deep lead. That contention is perhaps strictly correct, for the material on the bed-rock is not that of a typical stream deposit,—rounded pebbles, gravel and sand—but I have no doubt of its being a derived deposit, resting in a definite channel cut through a much older rock. Much of it is a cemented mass of angular and partly rounded fragments of quartz, with ironstone, white to reddish-brown clay and loam, and it owes its origin to water and wind action combined, as would be expected in a dry country like that part of Western Australia. This view is held apparently by the Geological Survey of Western Australia.

I may add that, in my opinion, the percolating waters of many deep leads contain gold in solution and that under favourable conditions small quantities of this gold are not infrequently deposited in suitable places in the underlying rocks, but I do not accept this origin for the formation of nuggets and of the finer gold found in deep leads.

W. LINDGREN: I did not intend to say that gold cannot be dissolved and re-deposited in placers, but only that it does not take place on a scale economically important. Regarding the deposit at Kanowna, in Western Australia, I believe that it is not a placer but the decomposed outcrop of a gold-bearing vein.

M. B. BAKER (Kingston): I would like to cite the placers of the Yukon as a specific instance where gold has crystallized at the base of a placer. There, as most geologists know, well rounded gravel rests upon the upturned edges of schists. The gravel is covered by frozen peat, muck or gravel. In the lowermost six inches of this gravel, just above the bed-rock, crystals of gold up to $\frac{1}{4}$ inch in diameter are found. I believe, however, that Professor LINDGREN is correct in saying that such cases are of scientific rather than of economic importance, and that no large percentage of such secondary gold is found.

E. MAIER (Santiago): Ich kann mich der Meinung Prof. KRUSCH's nicht anschliessen, dass Kupferglanz stets ein Zementationsmineral sein muss; in einer Mine im Aconcaguatale in Chile ist dies jedenfalls höchst unwahrscheinlich. Es handelt sich dort um eine Infiltrationszone in Andesiten, die bis in die feinsten Poren mit silberhaltigem Kupferglanze erfüllt sind. Ich kann nicht annehmen dass es sich hier um eine secundäre Ersetzung eines ärmeren Sulfide handelt, das die Poren des Andesits einmal geschlossen hatte und trotzdem die Möglichkeit hätte lassen sollen, dass eine neue Zementations-infiltration den Andesit zum zweiten Male so vollständig durchdrungen hätte, dass keinerlei macroskopische Spur des ursprünglichen Sulfids zurückgeblieben wäre.

Im Übrigen ist in den Kupfergängen von Chile der Übergang von der Zementations- zur primären Zone durch eine auffallende Erscheinung characterisiert; unter der Zementationszone folgt eine Zone von ganz kupferarmen Schwefelkiesen, und erst unter dieser kommt die Zone der guten primären Kupferkiese, die dann in grösserer oder geringerer Tiefe ganz allmählich verarmen.

Diese Erscheinung ist in Chile so häufig, dass sie wohl als primäre Verschiedenheit der betreffenden Tiefenstufen angesehen werden muss, ebenso wie der Übergang von Silber zu Zinn in Bolivien. In den dortigen Silber-Zinngängen nimmt der Silbergehalt nach der Teufe zu ab, während der Zinngehalt gleichzeitig zunimmt, was ich gegenüber der gegenteiligen weitverbreiteten Meinung einer Zunahme des Silbers in der Tiefe ganz besonders hervorheben möchte. So hat z. B. in der Mine Itos in Oruro der Silbergehalt, der in den obersten Bauen 4,000 g pro Tonne betragen hatte, bis zu einer Teufe von 420 m ganz allmählich bis auf 820 g pro Tonne abgenommen, während der Zinngehalt ebenso allmählich von 2% auf 20,5% gestiegen ist. Auch hier handelt es sich zweifellos um primäre Verschiedenheiten in der Gangausfüllung.

P. KRUSCH (Berlin) betont, dass er nicht sagt, es gibt keinen primären Kupferglanz und kein primäres Buntkupfererz sondern nur, dass er beide nicht kennt.

In allen Fällen wo ihm Freunde beide Erze zusandten, die sie für primär hielten, fand er die Reste älterer Erze im Buntkupfer und Kupferglanz. Die metasomatische Verdrängung (Zementationsmetasomatose) ist in vielen Fällen eine vollständige, so dass man mit blossem Auge nur Buntkupfer und Kupferglanz sieht.

Er würde dankbar sein, wenn ihm derartige primärer Erze nachgewiesen werden könnten.

Im Bezug auf die silberhaltigen Zinnlagerstätten Chiles erinnert er daran, dass man zwischen typischen Zinnlagerstätten mit Silbergehalt und Silber-Zinngängen unterscheiden muss, die den jungen Goldgängen nahestehen. Die ersteren können eine Anreicherung von Zinn nach der Tiefe zeigen.

W. LINDGREN: According to Dr. KRUSCH, bornite is secondary as far as his experience goes. Now it is interesting to note that Professor L. C. GRATON, with whose recent work Dr. KRUSCH doubtless is familiar, regards bornite as almost invariably primary. It seems to me that the interests of the science demand that Dr. KRUSCH and Professor GRATON be appointed a committee to investigate fully this important matter. The rest of us will look forward to their report with great interest.

W. H. EMMONS (Minneapolis): Many examples of secondary gold ores have gangues including the carbonates. In such rock the gold migrates only short distances and is precipitated at the top of the zone, where carbonates are being dissolved. This may be only a few feet from the surface. The distance through which gold may be carried depends upon the minerals present and the rates at which these minerals will reduce an acid sulphate solution. Calcite and pyrrhotite are among the minerals that react most readily to reduce the acid sulphate.

Sujet No. 4: L'origine et importance des sediments precambriens.

ILLUSTRATIONS OF THE FORMATION OF COMPOSITE GNEISSES AND AMPHIBOLITES IN NORTH-WEST IRELAND.

BY

GRENVILLE A. J. COLE,

Director of the Geological Survey of Ireland, Dublin.

The Dalradian series, so appropriately named by Sir A. GEIKIE, is represented in northwest Ireland by well bedded quartzites, shales (now mica-schists), and limestones, penetrated by basic igneous rocks, which are now in the condition of aphanites and diorites. Masses of granite have greatly modified this series, producing contact effects and composite gneisses on a regional scale. One of these granites commonly agrees in the general trend of its masses with the axes of Caledonian folding, while a later granite cuts across it. Both, however, may be of Pre-Cambrian age.

The banded gneisses of the area, which in hand specimens resemble much of the so-called "fundamental gneiss" of other countries, are clearly traceable into the sedimentary rocks, from which they have been derived by intimate injection of granitic material parallel with the layers of the stratification. In many places, as at Lough Derg in southern Donegal, the only relics of the absorbed Dalradian series are rounded or ellipsoidal masses of amphibolites (quartz-felspar-pyroxene-amphibole rock). These, no doubt, often represent undigested blocks of aphanite, but may in part be derived from limestone, as was discussed in a paper in the Transactions of the Royal Irish Academy in 1900. In the long ridge of the Ox mountains, the amphibolites are often drawn out by the flow of the granite into sheets, and the contortion of these sheets during the general softening and intermingling has produced a very striking gneissose structure near Ballintogher and Drumahair in County Leitrim. This has been ascribed by certain authors to dynamo-metamorphic action; but the stages that can be traced from the granite with blocks of amphibolite to the banded gneiss afford convincing evidence of the composite origin of the gneiss under the attack of the advancing granite magma.

Occasionally, as at Doocharry Bridge in County Donegal, only isolated sheets of mica-schist remain in a granitic mass; but these retain their parallelism with the strike of the sedimentary series, and are the last surviving relics of the Dalradian cover that has been, for the most part, eaten into and absorbed.

A striking example of the effect on bedded quartzite of nearness to a granitic cauldron was observed at Minaun Cliffs, Achill Island, County

Mayo, during the visit the Geologists' Association in 1912. The strata remain horizontally bedded in the great cliff section, except in their lower part, where veins of a coarse red granite penetrate them near the present shore line. The quartzites have here undergone intense crumpling and overfolding, such as one meets with on a large scale in mountain ranges, and this contorted flow seems to be entirely due to the yielding that has taken place in the region of heating on the upper surface of the granite cauldron.

The oldest rocks known in northwest Ireland are the Dalradian sedimentary series, and here, as in so many other countries, there is no evidence of the existence of anything like .. fundamental gneiss."

DIFFERENT TYPES OF PRE-CAMBRIAN UNCONFORMITIES.

BY

J. J. SEDERHOLM,

Director of the Geological Survey of Finland.

Where Pre-Cambrian sedimentary rocks have been found in great thicknesses and studied in some detail, they have usually been found to include several different series separated by unconformities. I shall here endeavour to show, by examples from the region which I have studied myself, what different types are represented by these unconformities.

THE SUB-CAMBRIAN UNCONFORMITY.

If we regard the Olenellus-zone as the bottom layer of the Cambrian, we find, both in Esthonia and in Scandinavia, sedimentary rocks underlying it in apparent or real conformity, viz., the Blue Clay, with its associated sandstones, and the Sparagmite of the Scandinavian mountains. While the Sparagmite, a coarse feldspathic sandstone of the same type as the Torridonian of Scotland, again reposes directly, and in apparent conformity, on the Jotnian Dala sandstone of Sweden, we find in the east a more marked unconformity between the Eo-Cambrian clay and its basement rocks. In St. Petersburg, borings have shown that the Blue Clay is in immediate contact with an underlying red gneissoid granite. Hence the Jotnian sandstones, in a zone which in all probability extended over a considerable area in southern Finland and in the vicinity of St. Petersburg, must have been removed by erosion before the deposition of the Cambrian.

The peculiar rapakivi granite of the island of Aland, between the Baltic and the Gulf of Bothnia, contains fissure veins in which have been found fossils belonging to the Olenellus fauna, from which it appears that the granite was exposed at the time of the deposition of the Olenellus sandstone. In Sweden, the rapakivi granite is covered by Jotnian sandstone, and the same has probably been the case also in western Finland, although it has been removed later by erosion.

Thus we find several supports for the conclusion, that there was a prolonged period of erosion before the beginning of the Cambrian, during which the Archæan and Jatulian were levelled, the youngest Pre-Cambrian granites uncovered, and the Jotnian sandstones deposited and in great part again worn away.

The apparent conformity between the Cambrian, the Sparagmite and the Jotnian sandstones in Scandinavia may, therefore, possibly be deceptive.

In any case, the Jotnian of eastern Fenno-Scandia was deposited long before the beginning of the Cambrian period.

Among the sedimentary rocks of northern Norway, in the formations which have been called Raipas and Gaisa, there may be deposits which fill up the gap between the Jotnian and the Cambrian, and between the former and the Jatulian. Also in southern Fenno-Scandia there are certain sedimentary rocks which lie horizontal like the typical Jotnian, but which are certainly older than the main part of the Jotnian. Thus, on the island of Hogland there are conglomerates and sandstones at the base of a great sheet of quartz-porphyry which is genetically connected with the rapakivi granite. The time of deposition of these sediments is separated from that of the Jotnian by the time required for the eruption and erosion of the quartz porphyry. The sandstones of Almesåkra in Sweden, in part slightly metamorphic, may also belong to the same *Lower Jotnian* rocks.

In all these cases we have to do with rocks which are entirely similar to younger sediments and have suffered very little disturbance in the region east of the Scandinavian mountain ridge. The unconformity between them and the underlying rocks is of the same character as, for example, that between the Vosgian sandstone of Baden and the underlying granite.

THE SUB-JATULIAN UNCONFORMITY.

Passing now to the underlying older formations, the quartzitic sandstones, conglomerates, argillites, dolomites, etc., belonging to the *Jatulian* system,[1] we again find these well separated by unconformities from the over- and underlying rocks.

The Jotnian rocks have never been found in direct contact with the Jatulian, but in Olonetz, to the northwest of Lake Onega, both systems are found near each other, the older always compressed into gentle folds and the younger, in the continuation of the strike of the former, lying nearly horizontally. The basic igneous rocks intercalated between their beds are, in the younger formation, unmetamorphosed, in the older always more or less completely uralitized. Moreover, the folded quartzitic sandstones and the associated basic rocks are penetrated by the unmetamorphosed rapakivi granites, whose eruption, as already stated, happened in Lower Jotnian time. These facts show that the folding of the Jatulian rocks, which took place over the whole area of eastern Fenno-Scandia and probably also over the western parts of it (Högbom and other Swedish geologists ascribe a Jatulian age also to the folded quartzitic sandstones, etc., of Dalsland, on the western shore of Lake Wenern in Sweden), happened in pre-Jotnian time. There seems to be now a general agreement among Scandinavian and Finnish geologists as to this point.

The Jatulian rocks, which comprise thicknesses of at least 3,000–5,000

[1] W. Ramsay separates the uppermost parts of the Jatulian, including also the coal-bearing rocks of Schunga in Russian Carelia and Suojärvi in Finland, from the remainder, calling them *Onegian*.

feet often begin with great masses of basal conglomerates lying directly on the quartzites, mica-schists, granites, etc., which are found as pebbles in them. As they often repose directly on granites, in part highly gneissoid, on arteritic migmatites or other rocks formed or metamorphosed at great depth, the unconformity with the older sediments, which are penetrated by many of these granites, is very well marked. Obviously there was a prolonged period of erosion before the deposition of the Jatulian sediments. Högbom, therefore, thinks that the unconformity at the base of this system may possibly be the greatest in the whole geological sequence.

THE SUB-KALEVIAN UNCONFORMITY.

When we pass, however, to other parts of Fenno-Scandia, we find that the gap between the Jatulian and the underlying rocks is in part filled up, the former lying directly on older sedimentary rocks which belong to the Kalevian system of Ramsay and Frosterus.

This system comprises great thicknesses (at least 10,000–20,000 feet) of conglomerates, quartzites, mica-schists, dolomites, limestones, etc., intercalated with basic eruptive rocks. All are more or less metamorphic, sometimes in a very high degree. However, some of the quartzites are still like sandstones, showing cross-bedding, occasionally even ripple marks, etc., but the others are schistose, or even gneissic in appearance, having been changed, in the neighbourhood of granitic masses, into entirely crystalline, granular quartzites of glassy appearance. The conglomerates often lie at the base and grade into the rocks of the basement, which were in a large measure altered by the same process of disintegration that gave rise to the associated breccias. By the later metamorphism of the altered rocks of the basement, schistose rocks originated which resemble augen gneisses, but whose foliation is certainly due to movements in rock masses which had been disintegrated by weathering.

The basal breccias and conglomerates, containing pebbles of the different rocks of the basement, including its granites, mark the unconformity against the older rocks in a conspicuous way. But there are also conglomerates in this system which contain only sedimentary and effusive volcanic rocks and mark an unconformity between two subdivisions of minor rank.

The unconformity between the Kalevian rocks and the overlying Jatulian is very marked. At some places, for instance in Olonetz and in Lapland, the Jatulian strata, dipping at a low angle, repose directly upon the upturned edges of the Kalevian. But the unconformity is still more marked by the fact that widely distributed granites penetrate the Kalevian, but were eroded to a great depth before the deposition of the Jatulian.

These granites follow the strike of the Kalevian zone from Lapland down to the neighbourhood of Ladoga. Thus, we have here an example of the fact common in the Archæan, that the better preserved supercrustal schists are *on the one side in contact with their former basement, and on the other with granites penetrating them.* At such places it is possible to determine with more success than elsewhere, and over great areas, the relative age of the rocks.

Although there are certain difficulties in determining the age of the granites correctly, especially as long as the mapping has not been executed in great detail over the whole region, I think the method of using not only the sedimentary schists, but also and quite especially, the granites, for correlation purposes is the most reliable. The protrusion of a great formation of granite and its subsequent exposure through long continued denudation are such important events in the geological history of a region that they cannot be regarded as due to local causes.

As long as the detailed mapping of such a region has not been completed, errors in the determination of the age of the granites are likely to occur and may necessitate modifications of statements which were anticipations. So, for example, our separation of the strongly metamorphic schists near Lake Ladoga from the Kalevian proper, as a much older subdivision designated Ladogian, was mainly founded on a correlation between the post-Kalevian granites at Lake Ladoga and the younger pre-Kalevian granites of western Finland which has now proved to be erroneous. Although it still seems probable that the Ladogian is somewhat older than the main part of the Kalevian, and that it is separated from the latter by an unconformity marked by basal conglomerates, it is at the present time difficult to differentiate these formations, and it may therefore be more practical to use the term Kalevian to cover them both.

The Kalevian is therefore a system of supercrustal rocks which exhibits in part the type common to the Algonkian rocks of North America, while in places where it has been injected with granites, it shows a decidedly "Archæan" character. Only in the former cases is the unconformity against its basement well preserved, and it is then often very conspicuous.

THE SUB-BOTHNIAN UNCONFORMITY.

Most geologists in northern Europe who have devoted their special attention to these oldest rocks agree in the opinion that there is at least one great system of sedimentary rocks underlying the Jatulian which is separated from its basement by a distinct unconformity. It is only when we reach the sedimentary rocks which I have called Bothnian and which are still older than the Kalevian,—since the basal conglomerates of the Kalevian contain debris and pebbles of granites that penetrate the Bothnian—that a general dissensus of opinion prevails.

Holmquist maintains the idea of the practical indivisibility of the pre-Kalevian complex, and feels uncertain regarding the manner of its origin. Högbom formerly recognized my Bothnian division and used it to include the schists of Skellefteå in Sweden, but has subsequently joined Holmquist in his sceptical position.

As to the *origin* of the Bothnian rocks in the typical area near Tammerfors, however, I think, that most petrologists will agree with me when I explain it as sedimentary. In fact, the phyllites of Näsijärvi, consisting of alternating sandy and clayey materials, have suffered so little metamorphism that many visiting geologists have found it difficult to believe in their Archæan age. But again, when we visit the contacts of these same rocks with what I regard as their basement, these same geologists often declare that the schists obviously are older than the adjacent gneissoid granites which belong to our oldest rocks. Thus my geological warfare in these regions has always been a fight with two fronts; against the geologists who declare at first sight that the schists are Cambrian, Silurian or later, and against those who declare that there is no definite boundary between these schists and the oldest Archæan.

Most of the areas of Bothnian schists lie at the margin of the great central area of granite. This granite is younger than the schists, always penetrating them in innumerable veins, and forming with them veined gneisses (migmatites). But on the opposite side of the schists there occur other granites, often more gneissoid, which do not penetrate the schists in the same way, and which, as well as some schists of sedimentary origin occurring in the same complex, I regard as belonging to the basement complex of the Bothnian sediments.[1]

There are nowhere any typical basal conglomerates at the contact with this older gneiss, although there are near it in one place conglomerates which contain pebbles derived from the basement rocks; and in one locality also, there is a peculiar brecciated rock which I regard as a diorite disintegrated by weathering in Bothnian or pre-Bothnian time. The primary features, however, have been obliterated in so great a degree by a subsequent granitization and strong metamorphism, that the relations are somewhat obscure.

Most of the rocks occurring at the bottom of the sedimentary layers were originally sandy or clayey. They are estuarine deposits, and the thickness of the single layers show that they have been deposited at the mouth of a considerable river. Conglomeratic layers are very rare in the lower part of this deposit. The pebbles which ought to have existed on the surface of the underlying rocks may have been swept away from most places by the current or the waves and have accumulated only at certain places along the contact-lines which are not now visible.

In very few places here do we find anything that can be regarded as the original contact between the sediment and its basement. The disturbances which have almost everywhere tilted the strata vertically have also caused overthrusts at the junction between the different formations which have mylonitized the underlying granites and sometimes pushed them in folds into the sediments.

Although this folding may give rise to rather intricate contact relations it does not make them entirely illegible. The absence in every case of indubitable dykes or veins of the granite at the contact has seemed to me to

[1] During last summer Dr. Mäkinen has been able to show with certainty that some gneissose granites penetrate at least part of the Bothnian schists, and the opinions expressed here may therefore be subject to revision.

be a sign of its older age; and in some cases the nature of the contacts seems to offer similar evidence. But where an intense granitization has also taken place along the contact lines, the geological record is very difficult, sometimes almost impossible, to unravel. Older and younger rocks together are changed into veined gneisses (migmatites) and their primary features become obliterated.

This has, thus far, been my explanation of the absence of well preserved basements in the Archæan. But I think that my studies of such contacts also show that, where younger granites occur extensively along the contact lines, detailed investigation can still detect there persistent primary features which will allow the relative ages of the rocks to be determined. Such a study of the contact lines should never be neglected. The conditions may be obscured by subsequent granitization, yet, wherever primary features of mineral composition or texture persist, it may be possible to recognize and interpret primary stratigraphical features.

UNCOMFORMITIES IN THE PRE-BOTHNIAN COMPLEX.

Hitherto, no unconformity has been found in the pre-Bothnian complex which has stood the test of criticism. I have described in another paper,[1] an instance of granitization or *anatexis* that shows how contacts may be partly or wholly obliterated by this process. These rocks are not often so well exposed as in the case cited, and it is still rarer to discover the primary contacts between sediments and their former basement in process of obliteration by anatexis. Anatexis has changed great areas of Pre-Cambrian rocks to migmatites that show few of their original features, yet there remains so much of the pre-Bothnian system, particularly in Sweden, that we may expect future research to add much to our knowledge of these older rocks, which include, for instance, the limestones and iron-bearing rocks of central Sweden and southern Finland, and of the unconformities within them. I have lately observed certain things which I am inclined to interpret as evidence of the existence of such unconformities.

[1] *On regional granitization (or anatexis.)*

ON REGIONAL GRANITIZATION (OR ANATEXIS.)

BY

J. J. SEDERHOLM,

Director of the Geological Survey of Finland.

So many theories of magmatic injection and the refusion of rocks have been advanced, both by the adherents and the opponents of regional granitization, that little can be added to them.

For my part, I have tried to develop in the field the petrographical study of mixed rocks or *migmatites*, and of the process by which granites work their way into adjacent rocks. I have spent several summers in mapping such regions in great detail, making drawings on a scale of 1:20 of surfaces up to 30,000 square feet in area, and taking many hundreds of photographs of the polished rock surfaces. And this work has been supplemented by microscopic study of rock specimens. I may claim, therefore, that the conclusions reached in this paper are not scientific whims, but are based on rather extensive field-work.

I shall begin with some cases of a granitization which is not regional, but offers the best clue to the interpretation of the phenomena in question. At the western contact of the largest area of the peculiar, coarse grained, porphyritic granites which are called in Finland rapakivi granites and are the youngest Pre-Cambrian granites in Fenno-Scandia, there are very interesting phenomena of penetration. The rapakivi massif is laccolithic or batholithic, the contact plane dipping obliquely under the adjacent formations —a very old, metamorphic plagioclase-porphyrite, and a red, slightly gneissoid granite. In these older formations, more than 1,000 feet from the contact, there are fissure veins of quartz, pegmatite and aplite which are connected with the rapakivi granite. *Fissuring* is thus the first phenomenon observed in approaching the granite. Nearer the contact, at a distance of 500–1,000 feet from it, the fissuring is connected with, and in part obliterated by, an intense granitization. Aplitic magma has been intruded along the broader fissures, and has also been absorbed through capillary openings in the schist, altering that rock to an intermediate type rich in orthoclase. This intermediate variety alternates with arteritic migmatites and exhibits in places the folding common in such rocks. Some narrow veins of aplite show this *ptygmatic* folding in a very typical form. It is a fluidal phenomenon of which I shall give other instances.

A portion of the schist next to the contact is highly aplitized and rich in orthoclase, but in some parts its original composition is better preserved. It may be seen that the aplitization proceeds from veins of aplite as if the adjacent rock had soaked up the magma. The aplitized schist at the contact is brecciated and the fragments contain porphyritic feldspars like those of the granite. This would seem to imply that an intimate penetration has taken place. No petrographer could visit this locality and remain skeptical regarding the possibility of a granitic magma intimately permeating the rocks adjacent to it.

Similar contact phenomena are observed in other areas of rapakivi granites. The adjacent rocks are brecciated for several hundred feet away from the contact and the fragments are cemented by a fine-grained aplite, which has also pervaded them so that inclusions and granite often grade imperceptibly into each other. Arteritic gneisses, often showing fluidal folding, also occur.

In a region neighbouring the first mentioned, there is another coarse grained porphyritic granite, the Onas granite, somewhat older than the rapakivi, which shows another modification of contact effect. The rocks adjacent to this granite are brecciated for 1 000–2,000 feet from the contact and are cemented by granite, which occurs partly as well separated veins, and partly as a constituent of gneissic migmatites.

These phenomena of granitization are now being studied in detail by Dr. Borgström.

In the same region, on the southern coast of Finland, there are other very old (pre-Bothnian) granites, which also show very interesting relations to the old metamorphosed basic volcanic rocks which they invade. Here especially eruptive breccias occur over wide areas and in manifold different varieties. At the margins of larger remaining areas of metabasites these rocks are very much dislocated and brecciated into fragments separated from one another by the granite. These fragments show signs of magmatic corrosion, and become gradually more and more subdivided, sometimes into many thousands of small pieces. This fragmentation was closely connected with the penetration of the aplite and the gradual fusion of some parts of the basic rock, the cracks resulting from beating and movements that affected the solid fragments in another way than the surrounding pasty magma. By putting fragments of a solid rock in a glass superheated under high pressure, we could perhaps imitate this process.

In some cases the fragments are so intimately pervaded by the granite as to become faded, and then the breccias change into what I call "nebulitic" rocks. Sometimes such rocks occur as inclusions in breccias composed of well defined fragments, hence the process has evidently been a complicated one. In other cases some parts of the basic constituents were dissolved and now form veins in the breccia, or certain parts of granitic veins contain more of the femic minerals and assume a dioritic composition. But, in general, the cementing granite does not appear to have been very conspicuously influenced by the basic rock which it dissolved. Some process of differentiation apparently counteracted the tendency to increasing basicity. Microscopically, the inclusions may show, next to the granite, a texture resembling that of a hornfels but with the minerals better individualized, the hornblende especially forming idiomorphic crystals.

These migmatites of metabasalt and pre-Bothnian granite are very common along the southern shore of Finland. But throughout the same area occurs another group of granites which are younger than the last mentioned, although very much older than the rapakivi granites. It is especially the granitization caused by these *post-Bothnian* granites that I have studied during recent years.

Certain dykes of metamorphosed basalts of presumably Bothnian age intersect the older rocks throughout this area. The relations of the younger granites to these metabasites and their adjacent rocks are of especial interest. I have already reported these phenomena at the Congress meeting in Stockholm, and shall now only summarize some of my results.

The simplest phenomenon is the formation of granitic breccias with angular inclusions, well illustrated on the little island Inderskärs Westgrund, that I have mapped on a scale of 1:20. Each of the dykes of metamorphic volcanic rock which intersect the fragments of older gneissoid granite in this island has a uniform composition. This circumstance allows the identification of its different parts, or a reconstruction of the "disjecta membra" of each dyke. Thus, the original position of these fragments, before they were separated by a network of penetrating veins—mostly pegmatitic or aplitic—of a younger granite can be ascertained. It can be seen that some fragments have been moved apart at least 35 feet, probably by a slow flowage.

There are also widespread evidences of magmatic resorption in connection with the formation of the veins. The fragmentation of the older rock masses did not take place at once by the formation of long intersecting fissures, but each fragment was repeatedly subdivided into smaller ones, by cracks that proceeded from the margin, and frequently did not intersect the whole fragment.

Somewhat different from these plutonic breccias with locally well preserved angular inclusions are the migmatites, in which granitic veins form a regular network in the older rocks and are often still more closely connected with these. That these rocks, which I have called *diktyonites*, originated through a more complete fusion of the older rocks than in the case of the plutonic breccias is shown especially by the behaviour of the basic dykes present. These are also interwoven with a network of veins and often highly contorted and crumpled. Especially is this the case on the small island of Spikarna, the rocks in which I have already described.

These contortions belong to the same series of phenomena as the ptygmatic folding of the granitic veins which I have already mentioned and of which I shall now show some typical examples. These mixed rocks occur in irregular aureoles around areas where purer granites prevail over the migmatites, for instance, in the region westward from Helsingfors on the southern coast of Finland.

The axes of the folds run so irregularly—often at right angles to one another,—that it is impossible to explain the phenomenon as due to folding of solid rocks. Moreover, the minerals of the veins show no conspicuous signs of mechanical stress even where the folding has been intense. The intensely folded veins are often abruptly intersected by others, the component mineral grains of which differ in no way from these of the former, and obviously belong to the same period of granitization. Some parts of the folded veins show vague contacts with the surrounding rock, their magma having permeated this after the folding had occurred. The basic dykes that intersect the older components of the migmatite, are partly folded in the same sinuous manner as are the granitic veins. No folding of solid rocks can imitate these structures but entirely analogous things occur in fluids, as, for example, the streams of foam in whirlpools. Ptygmatic folding is a kind of folding which occurs in a fluid or semi-fluid medium.

I have described on former occasions the peculiar instance of palingenesis or formation of a new magma by refusion *in situ* which is offered at the island of Påfskär. On this island a gneissoid granite and a "leptitic" schist intercalated with thin layers of limestone are intersected by two dykes of metabasalt. The older rocks have been changed by refusion *in situ* to a new granite, while the dykes, which serve as witnesses of the changes that have happened, preserve their original forms, although shattered into groups of fragments.

I have studied a still more convincing instance of palingenesis, or refusion, in the above mentioned area east of Helsingfors where pre-Bothnian granites are common. Here a whole island with a diameter of about 1,300 feet consists of a very old Archæan conglomerate, probably the oldest yet discovered in Finland. This is penetrated by true dykes of the pre-Bothnian metabasalts and was later intruded by, and partly dissolved in, the pre-Bothnian granite. There are also present zones of basic rocks that begin as true dykes intersecting the conglomerate and the structure of which is still recognizable. These dykes become broken into numerous fragments between which, and also at the contacts with the neighbouring conglomerates, the ever present granitic magma has penetrated, forming pegmatitic and aplitic veins. Where these veins accumulate the conglomeratic texture is in the same measure obliterated. At such points the schist was quasi-eruptive, in so far as it had begun to move and had penetrated between the fragments of the metabasalt. Hence the dyke has been brecciated and afterwards cemented by a migmatitic rock.

On the western shore of the same island the contact against certain schists is observable. The original relations were possibly those of an unconformable superposition, the margin of the mica-schist intersecting the schistosity of the conglomerate, but both rocks differ little in age. The mica schist is highly contorted. At the contact the conglomerate is often changed into a more or less massive rock which behaves like an eruptive, for it penetrates the schist as veins, even when it retains distinct vestiges of its former conglomeratic structure. Moreover, dykes of metabasite that cut both this rock and the conglomerate are pierced by these veins of palingenetic granite. Thus we have illustrated the gradual transformation of a conglomerate into a new magma. Chemical analyses show that the parts which behave as an eruptive possess almost the same composition as the best preserved facies of the conglomerate, while other portions, macroscopically more like a mica-schist, are richer in silica and poorer in alumina and iron oxides, thus tending to approach the composition of the intruding granite of the same region.

The following chemical analyses have been made by Dr. E. MÄKINEN

	1.	2.	3.	4.
SiO_2	60.30%	60.98%	68.23%	70.31%
TiO_2	1.18	1.06	0.89	0.38
Al_2O_3	15.90	15.28	13.00	15.45
Fe_2O_3	0.95	2.72	0.95	0.25
FeO	7.23	7.21	5.74	2.30
MgO	2.64	1.73	1.36	1.15
CaO	6.87	5.80	3.37	2.40
Na_2O	2.90	3.02	3.26	3.33
K_2O	1.44	1.76	1.57	3.91
P_2O_5	0.28	0.31	0.40	0.08
H_2O	0.88	0.66	0.82	0.62
	99.67%	100.53%	99.59%	100.28%

1. Schistose conglomerate of Pre-Cambrian age from the island of Viasholm in Perno, Finland.
2. The same rock altered to a palingenetic eruptive, intrusive in the neighbouring mica schist.
3. The same rock after having lost its conglomeratic texture; intrusive in a dyke of metabasalt.
4. Granite from the neighbouring island of Wester-Rysskar.

For most of these migmatitic rocks chemical analyses are of less value because the proportions of the constituent rock materials are so variable. For instance, in the above mentioned breccias, which consist of metabasalt, and the granite whose composition I have just quoted, there can be found every variation from pure metabasalt to pure granite. A long series of analyses could only corroborate this fact, as well as the conclusions drawn from the evidence in the field. They would of course, do much to elucidate the details. In the contact zone of the rapakivi granite there is a manifest tendency on the part of the rock masses pervaded by the granitic magma to segregate in basic and acid portions. Also, some parts of the metamorphic plagioclase-porphyrite have become so much richer in hornblende near the contact that they form very dark amphibolites, probably more basic than the mother rock; other parts are granitic in composition. There are also other signs that differentiative processes are very active among migmatites during the period of their formation. But different parts of the same zone behave in this respect very differently. Thus, in a zone where the pre-Bothnian metabasalts of Pellinge contain innumerable lenses, veins and dykes of post-Bothnian pegmatite and aplite, I found that the granite in many of these minor intrusive bodies has retained its granitic composition, although it must have procured room for itself by dissolving the metabasalt. Yet, elsewhere in the same zone such is not the case for a medium to coarse grained dioritic rock containing idiomorphic hornblende.

In chemical composition these rocks show a protean variety, and it will not be easy to discover the laws which have governed this variability.

Migmatitic rocks analogous to those which I have just described form an important part of the Archæan of Finland and the neighbouring countries that possess the same geological composition. They form about 25 per cent. of Finland; granites form over 50 per cent.; basic eruptive rocks less than 10 per cent.; and sedimentary and other supercrustal rocks, mostly in the form of metamorphic schists, only 15 per cent. Thus the regional granitization connected with refusion or *anatexis* of pre-existing rocks is a process which plays, perhaps, a more considerable rôle in the Archæan than metamorphism proper. Metamorphism has changed the rocks, but not often to such a degree that their primary petrographical features and stratigraphy cannot be easily interpreted. Anatexis has been more destructive, yet it has occasionally left patches which preserve remarkably well some of their original petrographical and stratigraphical characters. They show us glimpses of a vanished world and allow us to visualize many of the conditions that obtained therein. In such places where such glimpses are possible we may find the clue to the interpretation of a whole region. If the study of the rock masses affected by anatexis is much more difficult than that of metamorphic regions, it is also still more fascinating. I should be glad if I could convince my readers that it is not, as it appeared to myself not long ago, a hopeless task, but that methods can be devised to disentangle the confused structures of the migmatitic areas in the lowermost Archæan.

DISCUSSION.

A. C. LAWSON (Berkeley), said that granitization was a phase of magmatic resorption and that this question had been settled years ago; nevertheless, the details of Professor SEDERHOLM's paper were highly interesting. Some of these details indicated gentle and gradual resorption and, therefore, did not indicate the operation of magmatic stoping in the particular cases presented. Movements in the Pre-Cambrian rocks of Finland appeared to have been more intense than in those of the Lake Superior region, and the latter region was consequently the simpler of the two.

G. A. J. COLE (Dublin), thought that the Pre-Cambrian rocks of Finland were not so complex as Dr. LAWSON believed them to be, and that this apparent greater complexity was due to the Pre-Cambrian formations in Finland having been eroded to a great depth. He pointed out that some of the most interesting localities mentioned by Professor SEDERHOLM were easily reached from England by taking steamer to Hanau, and motor boat thence to Spikarne.

J. J. SEDERHOLM (Helsingfors), readily admitted the priority of the idea of refusion; he had been opposed to this theory, but had been converted to it by his field studies. He thought that Dr. DALY's stoping hypothesis explained satisfactorily the mode of formation of many eruptive breccias and kindred rocks. But such structures, he thought, were to be regarded as special cases; there were other "migmatite" structure in which the penetration of the magma had been slow and gradual.

THE PRE-CAMBRIAN SEDIMENTARY ROCKS IN THE HIGHLANDS OF NEW JERSEY[1]

BY

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The following paper is presented to the Congress (1), to furnish a sample of much of the Pre-Cambrian geology of the eastern United States; (2), to suggest in part the difficulty felt by the students of the eastern Pre-Cambrian in accepting the apparently complicated classifications based upon the phenomena observed in the Lake Superior region and the adjacent portions of Canada; and (3), to emphasize the fact that even in the greatly metamorphosed Pre-Cambrian areas in the central-eastern United States, distinctly characterized sediments may sometimes be found, and to intimate that their absence from other similar areas does not necessarily imply that they were never present in them.

In nearly all areas that contain Pre-Cambrian rocks close investigation has revealed the presence of sedimentaries well enough preserved to leave no doubt in the mind of the investigator as to their sedimentary character. The Highlands of New Jersey furnish no exception to the rule. The well-known white limestone, which contains the deposits of franklinite and zincite at Franklin Furnace, has been recognized as Pre-Cambrian by all geologists since the work of WESTGATE,[2] on Jenny Jump mountain, in 1894, and the work of WOLFF and BROOKS,[3] at Franklin Furnace in 1898. WOLFF and BROOKS named it the Franklin limestone.

It was not known until somewhat later, however, that fragmental rocks similar to some of those in the Pre-Cambrian series of the Adirondacks in New York, and of the Reading hills in Pennsylvania are associated with the Franklin limestone. SPENCER,[4] in 1908, mentioned thin layers of sandstone. In his description of the Andover mine[5] he declares that layers of siliceous breccia and indurated carbonaceous shales, aggregating 100 feet in thickness and outcropping for 1,300 feet, are associated with the ores. These dip

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[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] WESTGATE, L. C., Amer. Geologist, Vol. XIV, 1894, pp. 369-379, and Ann. Rep. State Geol. (N. J.) for 1895, pp. 21-26.

[3] WOLFF, J. E., and BROOKS, A. H., Eighteenth Annual Report, U. S. Geol. Survey, Pt. 2, 1898, pp. 431-457.

[4] SPENCER, A. C., Franklin Furnace folio (No. 161), Geol. Atlas U. S., U. S. Geol. Survey, 1908, p. 3.

[5] Ibid.

from 25° S. E. to nearly vertical. "The presence of coarsely crystalline white limestone in the vicinity suggests that the siliceous beds found at the mine are part of a series of sedimentary beds belonging with the white limestone of the Franklin region." Again at the Simpson and the Cedar Hill mines, near McAfee, he describes the hematite as occurring in layers or irregular deposits interbedded with layers of sandstone and shaly material that dip S. E. and are overlain by white limestone (p. 23). At the Cedar Hill mine "a stratum of hard green rock about 50 feet thick stands in a nearly vertical position between walls of white limestone. It contains abundant pebble-like, but more or less angular, fragments of quartz up to about one-fourth of an inch in diameter set in a matrix of chlorite, and throughout the mass, as seen near the surface, there is considerable red hematite in an amorphous or non-crystalline condition." This occurs in the interstices between the chlorite particles. BAYLEY[1] corroborates SPENCER's observations in the Franklin Furnace quadrangle and adds that the ore pits of the Fulmer mine, near Phillipsburg, are in a great mass of quartzite, south of which are yellow and light purple slaty or schistose rocks that resemble in many respects the sheared volcanics of South mountain in Pennsylvania. Some of the slates are very quartzose, and others are steatitic. Some are fine grained and dense, like rhyolites. Conglomeratic quartzite layers are interbedded with the slates, but they are not common. Farther northwest the slates are replaced by quartzitic conglomerates similar to those at the Andover, Simpson and Cedar Hill mines. The ore is merely a portion of the conglomerate more ferruginous than elsewhere in consequence of the presence of hematite in the interstices between the quartz grains. The white limestone occurs both north and south of the quartzites but the contacts are covered.

In addition to quartzites and slates there are also associated with the Franklin limestone in many places a fine grained, very quartzose mica-schist, which in some places contains a considerable content of graphite. In Tuxedo Park, N.Y., which is just north of New Jersey, STEWART[2] describes the limestone as occurring in a lens 250 feet thick and 3,000 feet long, surrounded by coarse-grained gneiss. With the limestone are associated pegmatite and a graphite-quartz-schist which consists of quartz, feldspar, biotite and graphite. The last two minerals are frequently intergrown with one another in alternate plates. Although its constituents are intercrystallized, nevertheless the rock is regarded as a sediment.

The limestone and associated schists at this place occupy an area a mile long and 20—300 feet wide, and are surrounded by gneisses. The beds strike N.E. and dip at a moderately high angle (30°–40°) S.E. Toward the northern end of the area the principal rock exposed is a coarse grained, gray marble composed of white calcite, large flakes of brown mica and irregular masses of brown chondrodite. Locally, it also contains considerable graphite.

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[1] BAYLEY, W. S., *Iron mines and mining in New Jersey;* Final Report Series, Vol. VII, Geol. Survey of New Jersey, 1910, pp. 77 and 84.

[2] BAYLEY, W. S., and STEWART, A. C., *Note on the occurrence of graphite schist in Tuxedo Park, N.Y.;* Econ. Geol., Vol. III, 1908, p. 535.

This limestone is cut by belts of pegmatite which run the length of the area, and by several small masses with oval sections. On the other hand, several small areas of the limestone are entirely enclosed in pegmatite and a small area of the same rock occurs off to one side of the main mass, at the contact of a pegmatite band with the country gneiss. At the extreme northeast end of the belt is a layer of graphite-quartz-schist which extends through the centre of the limestone. Its exposed length is 900 feet and its width is from 20 feet to 60 feet.

No limestone has been observed in the southwest portion of the area, where the series is represented by the graphitic schist alone. This rock occupies several long, narrow belts from several feet to 100 feet wide and entirely surrounded by pegmatite. It is so rich in graphite that it has been proposed to mine it.

The association of micaceous schist with the Franklin limestone is not by any means limited to the Highlands in New Jersey. MILLER,[1] in his discussion of the graphite of Pennsylvania, mentions that the mineral occurs in sedimentary deposits and igneous rocks that intrude them. Among the former he includes a white crystalline limestone, correlated with the Franklin limestone, which, he states, is associated with graphitic gneiss of which it is apparently merely a phase. He states that these acid gneisses were mapped with the Baltimore gneiss (Pre-Cambrian) by Miss BASCOM[2] on her map of the Trenton quadrangle, but on the forthcoming map of the Phoenixville quadrangle they will be designated by the distinctive name, Pickering gneiss. The gneiss is described by MILLER as being composed primarily of feldspar, quartz, biotite, hornblende, mica and graphite with pyrite pyrrhotite, magnetite, epidote, sillimanite, garnet and other alteration products of the primary minerals as accessories. It is [illegible] extremely variable in composition. Some layers are practically quartzites; others contain biotite but no graphite; others contain both biotite and graphite, while others contain so much calcite that they might fairly be called calcareous gneisses. In many places it is impossible to draw a sharp line between the Franklin limestone and the calcareous graphitic gneisses. "The two formations were formed originally as contemporaneous sediments that varied in different places. In some localities fairly pure limestone was being deposited while in adjacent regions were accumulating calcareous muds or siliceous muds in which there was little or no calcareous material. When these sediments were later metamorphosed, the beds composed mainly of calcareous matter formed the rocks called the Franklin limestone; the calcareous muds gave rise to the calcareous graphitic gneisses; the muds with little calcareous matter formed the bulk of the Pickering gneiss; and the more siliceous sediments formed the quartz-schists. If the limestone and the gneiss are conformable, as believed, with the limestone intercalated within the gneiss, the logical conclusion follows: that the two are of contempor-

[1] MILLER, B. J., *The geology of the graphite deposits of Pennsylvania;* Econ. Geol., Vol. VII, 1912, p. 762.

[2] Trenton folio (No. 167), Geol. Atlas U. S., U. S. G. S., 1908.

aneous origin and represent merely different lithologic phases of the same series of sediments."

In New Jersey, as has been stated, the Franklin limestone in many places is associated with slates, quartzites, conglomerates and micaceous

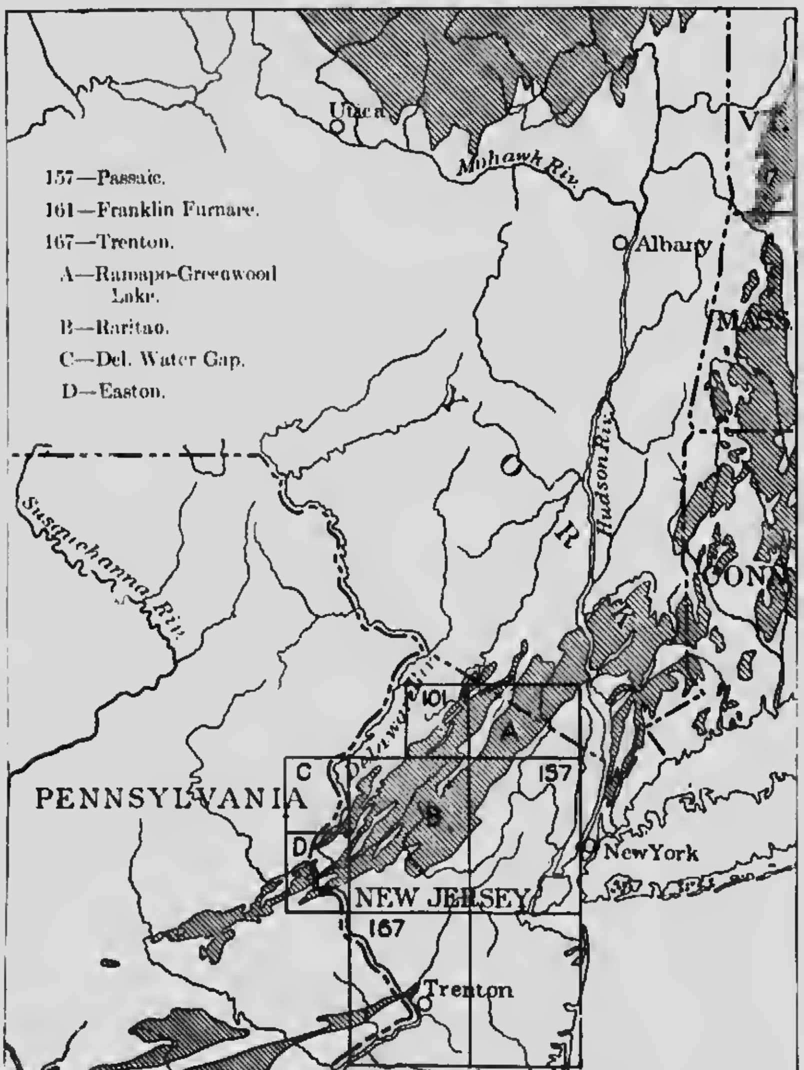

Fig. 1.—Sketch map showing areas of Pre-Cambrian crystalline rocks (shaded) in New Jersey and adjacent states, with the names of the quadrangles in New Jersey upon which folios have been published, or are in course of publication, by the U. S. Geological Survey. The names preceded by figures are of folios that have been published

schists. It contains also, in some places, layers of calcareous gneisses that are not very unlike those described by MILLER as being present in the Pickering gneiss. While limestone is the most prominent member of the series, and in some localities the only member observable, in other localities the clastic rocks are also prominent.

The most important exposures of the series are in the Delaware Water-gap, and the Easton and Franklin Furnace quadrangles.

A belt of limestone extends from the Pequest Furnace westward to Hazen, a distance of about two and a half miles, with an average width of about three-fourths of a mile. Here the predominant rock is limestone, which at one place is so richly impregnated with sphalerite that attempts have been made to mine it as a zinc ore. It varies from a fine grained white, gray, or bluish marble, containing a few quartz grains, pyrite crystals, graphite flakes and crystals of white pyroxene, to a mottled ophicalcite, containing abundant chondrodite, pyroxene, garnet, phlogopite, tremolite, magnetite, and an occasional crystal of tourmaline and sphene. In some places serpentine and talc are common. These components are especially abundant where the marble is cut by pegmatite or by dioritic intrusions. The only clastic rocks associated with the limestone in this area are a few thin beds of calcareous sandstone found in the quarries at its west end.

The Pre-Cambrian clastic rocks are best exhibited at Marble mountain,[1] several miles above Phillipsburg, in New Jersey, and on the opposite side of the Delaware river, along the south side of Chesnut hill, north of Easton, in Pennsylvania. At Marble mountain, the series of which the Franklin limestone is a part is represented by as complete a succession of beds as is found anywhere in the Highlands. These have been referred to above. The area is such an instructive one, however, that it is here described again in some detail. Besides the white limestone, there occur also quartzites, quartz-breccias or conglomerates, talcose slaty rocks and deposits of lean hematite. These rocks are intruded by great dykes of pegmatite and by masses of black, dioritic rocks. Exposures are not abundant, but, from those that have been seen, it seems safe to infer that the sedimentary rocks cover an area of about one square mile at the west end of the mountain. They occupy the little knob overlooking the Delaware river and the lower slopes of the ridge for a distance of a mile from this river. Within the area are several quarries which are worked for serpentine and talc, and several open pits that were sunk in the search for hematite. A fault bounds the area on the north and separates the Franklin limestone from gneisses. Considerable movement took place along this fault, contorting the limestone and producing several metamorphic minerals, of which serpentine and talc are the most abundant. The rock is mined, crushed, and sold as mineral pulp. The limestone of this area is similar in all respects to the Franklin limestone in other areas. The quartzose and slaty rocks are closely associated with the limestone but contacts between them are covered.

[1] PECK, F. B., *The talc deposits of Phillipsburg, N.J., and Easton, Pa.*; N.J.Geol Survey, Ann. Rept. for 1904, pp. 161-185.

The slaty rocks comprise very schistose, light yellow or gray schists, containing a little talc, and almost massive, dense, black jasperoid beds that look very much like ancient rhyolites. With these are interbedded a few layers of quartzite conglomerates and enclosed in them are lenses of quartzite. A few of the beds are strongly ferruginous. The iron is mainly in the form of hematite, which in some cases is nearly uniformly distributed through the rocks, and in others is segregated into discs and nodules. Garnet and tourmaline are often present in both slates and quartzites. Tourmaline is especially noteworthy as it sometimes occurs as black crystals an inch or more long and one-third of an inch thick. It is particularly abundant in very schistose phases of the slates.

Thin sections of the slaty rocks show grains of hematite and magnetite in an exceedingly fine textured aggregate of chlorite and some micaceous mineral. In some sections there is a suggestion of diabasic structure in the arrangement of the dark grains in the light coloured micaceous aggregate. In others flow structure is suggested by the occurrence of the dark grains in curving and wavy streaks through the lighter matrix. On the other hand, a few sections show the dark grains in a series of parallel lines as though marking bedding, and in others lenses of the light aggregate are surrounded by hematite and magnetite as though representing pebbles in a matrix which has been replaced by iron oxides.

The general aspect of the slaty rocks is that of a series of interbedded sediments and volcanic flows that have been squeezed and metamorphosed, but no decisive evidence can be cited to determine their origin. The rocks are strongly suggestive of the Pre-Cambrian volcanic series of South mountain in Cumberland county, Pennsylvania.

The quartzites and conglomerates, which are thought to be beneath the slates, differ only in the presence of lenses of white quartz in the latter. Both are vitreous, dark gray rocks with a splintery fracture and a structure that shows no trace of foliation or schistosity. They vary from very fine grained phases to those in which the particles measure several millimetres in diameter. Occasionally they contain small subangular fragments of dense greenish-black rocks resembling the dark massive slates, but otherwise they possess no noteworthy features. The lenses of white quartz in the conglomerates vary in size from particles as small as a pin's head to others two inches in diameter. Some are round, others lenticular and others angular. The larger fragments are fractured as though crushed, and little tails of quartz mosaic extend from the ends of the lenses. The matrix in which these lie, and the entire mass of the non-conglomeratic quartzites, consist almost exclusively of quartz and hematite. The quartz is in small particles that may be sand particles, in little crescentic fragments, and in little lenticular masses of quartz mosaic, all of which lie in a finer grained ground mass composed of quartz grains, hematite and magnetite. In some cases there are also present a little secondary quartz and a few needles and large crystals of black tourmaline. All the rocks contain hematite, and it is to this constituent that their dark colour is due. The hematite is so abund-

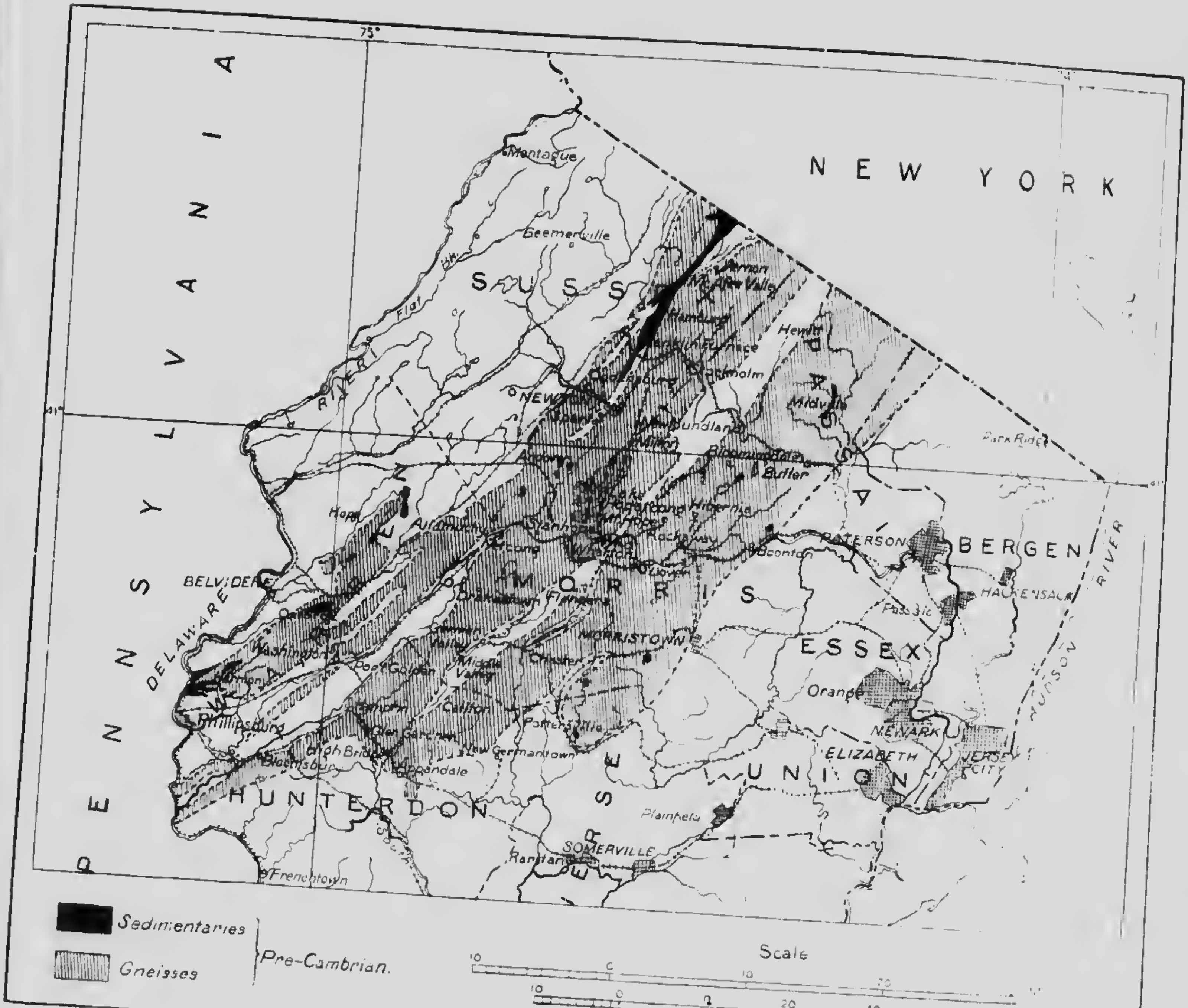

Fig. 2.—Distribution of Pre-Cambrian sedimentary rocks in the Highlands of New Jersey.

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Other exposures
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[1] Loc. cit., p. 181-2.

n some beds, and especially in the bottom portions of beds that are y thickened into lenses by folding, that attempts have been made to the rock as iron ore. Some thin beds consist of almost pure hematite, his is often sheared to schistose masses resembling the specular ore of Iarquette district, in Michigan.

n addition to the distinctly sedimentary rocks that have been described, are present also at Marble mountain a number of rocks of doubtful . One group of these questionable rocks is described by PECK[1] as coloured, sandy, or highly feldspathic gneisses that contain so much nate as to effervesce briskly with hydrochloric acid." They are de- to be interstratified with the limestones, slates and quartzites. So seen by the writer, the contacts between these siliceous rocks and the one are either fault contacts or intrusive ones. The sandy gneisses pparently the ordinary gneisses into which some calcite has been in- ed from the limestone which they intrude.

he second group of questionable rocks includes black augitic gneisses ning calcite or dolomite in thin laminæ. They weather readily into ic phases and, when sheared, pass over into rocks containing much and resembling biotite-schists. Some of these dark gneisses may ses of the limestone that have been so completely metamorphosed by ons of pegmatite and the material that produced the ordinary gneisses region that nearly all their original material has disappeared, and in re have appeared diopside, hornblende, oligoclase and a little calcite, g an aggregate of equal sized grains which is practically identical with omposing the more massive types of the black Pochuck gneisses, that common in the Highlands.

e main mass of Chestnut hill, on the west side of the Delaware river, e Marble mountain, is gneiss, but on its south slope is a belt of imestone several hundred yards wide and extending the full length hill for a distance of about four miles. At its east end, near the river, t splits into two limbs that are separated by a mass of pegmatite. estone is of the same character as that on Marble mountain, but there uartzite associated with it. It is strongly serpentinized and in places s a great deal of talc. On its north side the limestone is everywhere act with gneiss, and at its west end it is bordered by the Kittatinny e. This boundary is evidently along a fault.

mall exposure of the same limestone has been opened up by a quarry orth side of Bushkill creek about half a mile north of the west end of t hill. This is surrounded by the Kittatinny (Cambro-Ordovician) e, from which it is separated by faults.

er exposures of the series near the Delaware river are at Lower y and Roxburg. At Lower Harmony the series is represented by e cut by a few dykes of pegmatite. Certain beds have developed some light green hornblende, some biotite and a little tourmaline.

. cit., p. 181-2.

Others contain a few lenses of coarse feldspar mixed with light and dark green hornblende and some tourmaline. At Roxburg the white limestone is exposed in two small openings on the slope of Scott's mountain east of the village of Roxburg, where it exhibits its usual characters.

On Jenny Jump mountain, in the Raritan quadrangle, the limestone appears as a discontinuous belt lying to the east of the main crest of the mountain, as a narrower strip at the bottom of its east slope, and in a broad area at its northeast end. Much of the limestone contains the usual contact minerals, chondrodite and pyroxene, and at one place the rock is changed to a coarse grained, pink and white aggregate of calcite, dolomite, and phlogopite, that looks like a coarse grained, pink granite. At the end of the mountain there are associated with the limestone layers of fine grained, thinly bedded, micaceous, gneissic rocks. Some of these consist of quartz, feldspar, sillimanite, biotite and tourmaline. Others are composed of quartz, feldspar and pyroxene, or of the first two minerals and hornblende. The most common, however, are biotite-quartz-schists, with or without graphite, like those occurring at Tuxedo Park. In some places these rocks are crushed and much muscovite is developed in them.

The largest area of the Franklin limestone is that in which the Franklin Furnace zinc mines are situated. This begins a little south of Ogdensburg, and extends northeast with an average breadth of about three-fourths of a mile through Franklin Furnace, Rudeville and McAfee, a distance of fifteen miles to the north boundary of New Jersey, crossing the line into New York near Amity. Although this area is occupied almost exclusively by limestone, thin beds of quartzose rock are known to occur in it at a few places, as for instance at the Simpson and Cedar Hill hematite mines already referred to.

The only other area in which fragmental rocks are known to be associated with the limestone is the narrow belt in which the Andover and Tar Hill mines are situated, which has already been described. Finally, in several little pits west and southwest of High Bridge there are exposures of a mica-graphite-schist that is similar to the graphitic schists at Tuxedo Park. There is no white limestone in the vicinity, but the High Bridge schists are so like those at Tuxedo Park that it is reasonable to regard the two as belonging in the same series.

All the other areas in New Jersey in which the Pre-Cambrian sediments are known to occur are small, and none of them show any rock but the limestone, which in many places, however, is so completely metamorphosed that little of its original character remains. The most important of these, in addition to several detached areas in the Franklin Furnace quadrangle, are: two belts south and southwest of Stag pond, a small area west of Wright's pond, two small quarries east of Cranberry lake, the Roseville mine, the Split Rock Pond mine, a quarry south of Brookside, a quarry at Turkey mountain, two miles north of Montville, and a narrow belt at Stonetown. The last named area is two and a half miles long and only about 150 feet wide. In some places the limestone is so completely silicified that it resembles chert.

There have been no facts observed in the New Jersey Highlands that will serve as a means of separating the Pre-Cambrian sediments into a younger and an older series. The close similarity that exists between the Pre-Cambrian geology of New Jersey and that of the Adirondacks and eastern Ontario, however, suggests a correlation between the three areas. Rocks identical with those in New Jersey have been found in the two northern regions. Here they had been generally known as the Grenville series until MILLER and KNIGHT,[1] in 1907, subdivided them into a younger (Hastings) and an older series, separated by an unconformity. The younger series is correlated with the Huronian (Algonkian) of the lake Superior region and the older series with the sedimentary portion of the Keewatin (Archæan) series in the same region. For the latter the name Grenville is retained. This series, which consists largely of limestone, was deposited on a basement of spheroidal and ellipsoidal greenstones. In New Jersey no trace has yet been found of the basement on which the Pre-Cambrian sediments were laid down; consequently, it is not possible to decide whether they should be regarded as Grenville or Hastings. In their lithological features they resemble more closely the Grenville than the Hastings rocks. Even though they be correlated with the former, doubt still remains as to whether they are Algonkian or Archæan, since the position of the Grenville beds has not been definitely established. The existence of the quartzites and conglomerates at Marble mountain indicates clearly that, at the time the sedimentary series was laid down, a land area was furnishing sand and pebbles. Although no traces of this land have yet been found in the Highlands, its former presence is assured through the evidence of the rocks laid down off its shore.

The relations of the Pre-Cambrian sediments to the gneisses, in the midst of which they generally lie, are not clear. In many instances the contacts are along faults. In other cases they are apparently igneous. The smaller areas occupied by the Franklin limestone are elongated in the direction of the schistosity and banding of the gneisses, and mine pits seem to show that in some instances the limestone extends downward as narrow plates or lenses interlaminated with the gneiss. In still other cases limestone and slate are surrounded, above and on both sides, by gneiss. Moreover, the limestone is frequently intruded by pegmatite that is believed to be connected genetically with the gneisses, which are thought to be of igneous origin. The linear structure, which is characteristic of the gneisses in the region, is regarded as the direct result of flowage of a viscous magma and of its crystallization under the influence of the strains produced by the flowage.[2]

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[1] MILLER, W. G., and KNIGHT, C. W., *The Grenville-Hastings unconformity and the probable identity in age of the Grenville limestone with the Keewatin iron formation of the Lake Superior region;* Sixteenth Ann. Rept. Bur. Mines, Ontario, 1907, pp. 221-223.

[2] Compare BAYLEY, W. S., Passaic folio (No. 157), Geol. Atlas U. S., U. S. G. S., 1908, p. 2, and SPENCER, A. C., Franklin Furnace folio (No. 161), Geol. Atlas U. S., U.S.G.S., 1908, p. 2.

The magmas are thought to have intruded a series of pre-existing sediments and to have assumed their present structures as the result of the control exercised by the arrangement of the sedimentary beds. The larger areas of the sedimentary series may represent remnants of a more widely spread series of beds that were broken up and partly absorbed in the material of the gneisses; and the small areas surrounded by pegmatite or gneiss may be simply fragments that were floated from their original positions but not completely dissolved.

From the brief descriptions that have been given, it will be realized that the Franklin limestone is only one member of a Pre-Cambrian series of rocks including, in addition to the limestone, also quartzites, conglomerates, slates and micaceous schists. Many of these rocks have been so thoroughly metamorphosed that their fragmental character is greatly obscured. There can be no doubt, however, that they are sediments older than the gneisses which surround them, and that they represent a continuous deposition in Pre-Cambrian seas. Farther southwest, in Pennsylvania, as has been related, Miss BASCOM proposes to separate the clastic sediments from the limestone and to call them the Pickering gneiss. MILLER, however, thinks that there is a gradation between the two formations and that they represent a single period of sedimentation. In New Jersey the clastics and the limestone cannot be separated for purposes of mapping. It is probable that the white limestone in Pennsylvania can safely be regarded as the equivalent of the Franklin limestone; but that the Pickering gneiss is equivalent to the quartzites, conglomerates, slates and micaceous schists of New Jersey is not so evident. The great variety noted in the igneous gneisses of the area may be due in part to the assimilation by their magmas of the sedimentary rocks that have disappeared.

RELATIONS OF THE PLANE OF UNCONFORMITY AT THE BASE OF THE CAMBRIAN TO TERRESTRIAL DEPOSITION IN LATE PRE-CAMBRIAN TIME

BY

C. K. LEITH,

Professor of Geology, University of Wisconsin, U.S.A.

The great Pre-Cambrian plain over which the Paleozoic seas advanced for much of North America extends over the Lake Superior Pre-Cambrian rocks. Prior to the advent of this sea in the Lake Superior region there was terrestrial sedimentation, vulcanism and deformation on a large scale, represented by the Keweenawan series. Tilting of the Keweenawan rocks was progressing during their deposition, with the result that late Keweenawan sediments are lying nearly flat while earlier Keweenawan beds are tilted at angles up to 65°. This tilting developed the Lake Superior syncline. Terrestrial deposition was going on in this syncline until the arrival of the Cambrian sea. Cambrian marine sediments were then put down in structural conformity with late Keweenawan sediments, although showing marked discordance with earlier Keweenawan sediments. It is difficult to draw an exact line between the late Keweenawan sedimentation and the Cambrian sedimentation. One apparently merged into the other.

As the first Cambrian deposits are Upper Cambrian, the question is raised whether the immediately underlying late Keweenawan sediments should be classed as Middle or Lower Cambrian or Pre-Cambrian. Some of them probably overlapped the interval between Algonkian and Upper Cambrian sedimentation and are equivalent in age with Middle or Lower Cambrian. Nevertheless, for reasons which I do not here go into, we have regarded the Keweenawan in its lithology and structure as more closely allied as a whole to the Pre-Cambrian than to the Cambrian.

Whatever the ultimate classification of the Keweenawan, it is a great sedimentary and volcanic series deposited in a slowly developing basin in Pre-Cambrian rocks essentially before the advent of the Cambrian sea, and the series as a whole rests immediately under, and is cut by, the great plane at the base of the Paleozoic formations of the Mississippi valley. Terrestrial deposition of the Keweenawan played a part in developing this plane. As the lower Keweenawan rocks were tilted during the development of the Lake Superior syncline they were cut off by erosion and redeposited in low-lying areas principally within the syncline, thus tending to even up the surface by a cut-and-fill process. In other words, there is a close genetic

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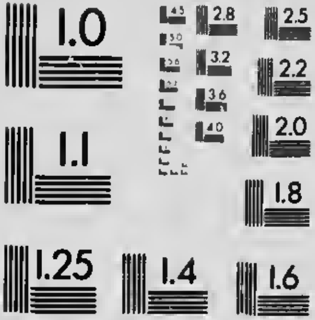

relationship between the existence of terrestrial sediments at the top of the Lake Superior Pre-Cambrian and the great plain bottoming the Paleozoic trangression. This conception does not imply that peneplanation or marine cutting following the sub-aerial deposition did not also play important parts. But they were not alone responsible for the plain. The fact that terrestrial sediments were not removed is in itself evidence on this point.

This raises the question as to what extent the pre-Paleozoic plain, so widely developed over the United States and elsewhere, may have some genetic relationship with terrestrial sedimentation in late Pre-Cambrian time. It seems to be something more than a mere coincidence that at so many places at the surface of this plain there are Pre-Cambrian terrestrial or delta deposits, resting with only slight discordance beneath the Paleozoic. The Belt series of Montana and British Columbia is regarded by recent observers as partly or largely terrestrial or of delta origin. The discordance of structure between it and the Cambrian is a slight one. Similar terrestrial deposits, probably of the same age, are recognized in similar relations to the Cambrian in scattered areas throughout our West, including the Wasatch mountains and the Grand Canyon of Colorado. The gold-bearing slates of Nova Scotia and the Avalon slates of Newfoundland may be found to be delta deposits of late Pre-Cambrian age. In Scotland the late Pre-Cambrian Torridonian sediments are regarded as a terrestrial deposit. They are similar to the Keweenawan sediments of the Lake Superior region. In structure they are but slightly discordant with the overlying Cambrian.

Without discussing these illustrations in detail and without arguing that all of them are valid illustrations, it seems to me likely that as a whole they present suggestive similarities to the Lake Superior situation in showing a genetic relationship of terrestrial sedimentation to the Pre-Cambrian plane of unconformity.

I wish to put forth the tentative proposition that the plain at the base of the Paleozoic was partly developed by the cutting and filling attendant upon terrestrial sedimentation in late Pre-Cambrian time; that it is something more than a mere coincidence that so many of the late Pre-Cambrian formations are of terrestrial or delta origin, and that they may be the natural accompaniments and consequences of the development of this plain.

The manner of the development of such an even and wide-spread plain as that beneath the Paleozoic in various parts of the world is a problem presenting difficulties which we should be glad to have cleared up for us by physiographers. In discussing this problem with geologists and physiographers I have been struck with the lack of agreement as to the manner of development of such a plain as that beneath the Cambrian. I present this paper with a view to inviting discussion which may enlighten us. Depending as largely as we do on physical conditions in our interpretation of the Pre-Cambrian, it seems to me that one of our next essential steps is to find out more about the matter of formations of plains of this sort.

Following the lead of English geologists, the older view has been that a plain like that here discussed has been formed by marine planation, preceded of course by more or less sub-aerial erosion. The development of the peneplain idea by DAVIS and his associates has led in some quarters to emphasis on sub-aerial erosion at or near sea-level as the chief factor in developing the peneplain, and to the exclusion of marine cutting. More recently WALTHER, DAVIS, and others have recognized desert weathering and wind erosion and terrestrial deposition as factors in developing plane surfaces at altitudes high above the sea (leveling without base-leveling); but this conception, so far as I know, has played little part in the interpretation of some of the great planes of unconformity in geological history. It seems to me that in the case above cited it may be an important consideration.

The peneplain idea, as ordinarily understood, involves the complete removal of all sediments down to grade prior to the encroachment of the sea. The fact that large masses of Pre-Cambrian terrestrial sediments have not been removed, although some of them appear to have been unconsolidated at that time, must mean that they were warped below the peneplain grade. The same is true if the surface were largely cut by marine planation.

The rôle of terrestrial sediments, therefore, in forming the remarkable plane at the base of the Cambrian, was that of filling depressions below the grades determined either by peneplanation or marine cutting.

DISSCUSSION.

A. C. LANE (Boston): I am very glad that Dr. LEITH and I are now in perfect accord as to the facts—that part of what has generally been called Upper Cambrian is very closely allied to the Upper Keweenawan, that in fact, in the centre of the Lake Superior basin the Upper Cambrian probably, at least apparently, succeeds the Upper Keweenawan conformably, and that the unconformity of the marine Upper Cambrian transgressing on the basement beds of a volcanic land formation like the Keweenawan does not imply of necessity a different period. To me the relations of the strata at the beginning of the Paleozoic seem like those of the Old Red sandstone of Scotland and the Devonian of England, or the Triassic of Germany and the Alps, and the "Red beds," Permian-Triassic, of the West. The final settlement of the controversy can hardly come by finding fossils in a Cambrian land formation, but rather in one of two ways.

In the first place the Keweenawan is the last volcanic epoch of the Lake Superior region. The nearer the Olenellus zone can be found with or without signs of contemporaneous volcanic activity the more likely will it be that the Keweenawan is or is not Cambrian.

Secondly, if I understand Dr. LEITH aright, he would agree with me that the Keweenawan was also formed during the last great diastrophic period of uplift, prior to the Upper Cambrian (St. Croix). Now, are the stratigraphic relations of the Olenellus zone such as to indicate that it was separated from the Saratogan or Upper Cambrian by any great diastrophic uplift, and how near to the Lake Superior region can such relations be traced? The nearer such uplift separating the Olenellus zone from higher beds can be traced the more likely is it that the Keweenawan occurred during such uplift.

J. J. SEDERHOLM stated that, in Fenno-Scandia also, the rocks immediately beneath the Olenellus zone were undisturbed, and that a notable general similarity existed between the Cambrian and Keweenawan rocks of these regions.

JOHN HORNE (Midlothian), said that in Scotland, on the contrary, there were clear evidences of movement during the interval between the deposition of the Torridonian sandstone, and the Olenellus shale, and that the Torridonian formation must have been disturbed by this movement.

Sujet No. 5: Les subdivisions, la corrélation et la terminologie du precambrien.

THE SUBDIVISIONS AND CORRELATION OF THE PRE-CAMBRIAN ROCKS OF THE BRITISH ISLES.

BY

A. STRAHAN, Sc.D., F.R.S.,

Director of the Geological Survey of Great Britain.

In this paper I propose to summarize briefly the results obtained from a study of the Pre-Cambrian rocks of the British Isles, so far as regards their subdivision and correlation. Though the exposures are fairly numerous, they are for the most part small in extent and isolated. They enable us, for example, to see that rock-groups varying greatly in type underlie the Cambrian in various parts of the British Isles, but in the majority of cases the relations of these groups to one another are not open to examination. The opportunities, therefore, for establishing a succession are less good than those which are presented in such regions as northern Canada or Scandinavia. Moreover, the difficulty is increased by the fact that those regions in which the greatest extent of Pre-Cambrian rocks is exposed to view, are all situated in areas of regional metamorphism. Not only have the relative positions of the rock formations been greatly changed by mechanical disturbance, but the original rock structures have been disguised by structures due to deformation. These remarks apply to a large part of the Scottish exposures, to the Irish occurrences, and to Anglesey and the Lizard.

Rocks proved or inferred to be of Pre-Cambrian age are exposed to view in the following parts of the British Isles:

1. *Scotland.* The Northwestern Highlands and the Highland complex.

2. *Ireland.* The Northern and Northwestern region and Carnsore Point.

3. *England and Wales.* Anglesey and North Wales; the Longmynd, the Wrekin, Rushton and Malvern; Caldecote (Warwickshire); Charnwood Forest (Leicestershire); St. Davids (South Wales); the Lizard (Cornwall).

I. SCOTLAND.

The following account of the Pre-Cambrian rocks of Scotland has been kindly supplied by Dr. J. Horne, F.R.S.

The Northwest Highlands

In this region two well-defined rock groups, of widely different lithological characters and separated from each other by a marked unconform-ability, are unquestionably of Pre-Cambrian age. They are known respectively as the Lewisian (or Hebridean) gneiss and the Torridon sandstone.

The Lewisian gneiss.—Along the western sea-board of the counties of Sutherland and Ross, and in the Outer Hebrides, the members of this group are typically developed. On the mainland they have been arranged in two divisions: (1) a Fundamental Complex composed mainly of gneisses and schists that have affinities with plutonic rocks, with a limited development of quartz-schists, graphite-schists, and limestones, evidently of sedimentary origin; (2) a great series of ultrabasic, basic and acid igneous rocks intrusive in this complex in the form of sills, dykes, and irregular veins. The various types of gneiss have a definite geographical distribution and they were subjected to earth-movements which have produced new structures in the gneiss and intrusive dykes and sills. All the members of this group in the west of Sutherland and Ross have been termed Lewisian gneiss by the Geological Survey after the island of Lewis in the Outer Hebrides.

Torridon sandstone.—Upon the Lewisian gneiss there rests unconformably a great succession of red sandstones and grits, with conglomerates, flagstones, dark shales, and calcareous bands. In the region not affected by post-Cambrian movements these strata are quite unaltered. Everywhere the evidence of prolonged denudation of the Lewisian gneiss in pre-Torridonian time is most marked. In places these unaltered sediments fill pre-Torridonian valleys to a depth of 1,500 feet. Sometimes the conglomerates contain pebbles of quartzite showing contact alteration, spherulitic felsites and other rocks, which are not now found in place in the west of Sutherland and Ross. Such evidence clearly shows the extensive denudation of the Archæan plateau. The arkoses display many of the phenomena characteristic of the New Red sandstone of the British Isles. From the fresh character of the felspars and the presence of dreikanter in these deposits it may be inferred that they were accumulated under arid conditions. The sun-cracked and rain-pitted surfaces of some of the beds point to their deposition in shallow water. In dark micaceous shales belonging to the highest division of the system, phosphatic nodules have been found. In these nodules Dr. TEALL has detected spherical cells with brown fibres which appear to be of organic origin. In the districts not disturbed by post-Cambrian movements the various divisions of the Torridonian sandstone reach a thickness of 10,000–12,000 feet. In the thrust masses in Skye the lowest division of the system (the Diabaig group) occurs in a greatly expanded form, the thickness being upwards of 7,000 feet.

At the close of Torridonian time the Pre-Cambrian rocks were folded and denuded. On this eroded platform, composed partly of Lewisian gneiss and partly of Torridon sandstone, the Cambrian strata, including the *Olenellus* zone, were laid down. The remarkable uniformity of this plane of erosion is a striking feature, and there can be no doubt that it represents the sea-floor on which the Cambrian sediments were accumulated.

The crystalline schists of the Highland Complex.

Between the Moine thrust plane and the eastern border of the Highlands there is a broad tract of crystalline schists, the age and structural relations of which have not been definitely determined. The Eastern schists, comprising the Moine series of the Geological Survey and certain inliers of Lewisian gneiss, have been traced from the Moine thrust plane across the counties of Sutherland, Ross and Inverness, beyond the Great glen to the Grampian hills.

The prominent types of rock forming the Moine series are: (1) phyllitic schists, siliceous schists, and limestones; (2) psammitic quartzo-felspathic schists and (3) pelitic muscovite-biotite-schists or gneisses usually containing garnets. In certain areas intrusive sheets of amphibolite, epidiorite, and hornblende-schists appear in the psammitic and pelitic rocks and share in the folding and metamorphism of the Moine series. The work of the Geological Survey has further shown that there is a gradual increase in the grade of metamorphism as the Moine schists are followed eastwards from the Moine thrust-plane. It is generally admitted that these phyllitic, psammitic and pelitic schists are of sedimentary origin, for in certain localities the original pebbles and clastic grains can still be recognized.

The inliers of Lewisian gneiss consist of hornblendic and micaceous gneisses with basic and ultrabasic intrusions which resemble lithologically certain types of Archæan rocks beneath the Torridon sandstone in the west of Sutherland and Ross. For this reason they have been correlated with the Lewisian rocks of pre-Torridonian age. At Glenelg and other localities these orthogneisses of the Lewisian inliers are associated with paraschists and gneisses of sedimentary origin, as for instance mica-schists, graphite-schists, kyanite-gneiss and limestones. It has been suggested that this sedimentary group may be the equivalent of the pre-Torridonian sedimentary schists in the west of Ross-shire (Letterewe).

From the relations which these various rock groups bear to each other in the field it has been inferred that the Moine schists rest unconformably on these inliers of Lewisian gneiss, the latter having been ridged up along isoclinal folds and exposed by denudation. Both the Moine schists and Lewisian gneiss have been affected by a common system of isoclinal folds and by common foliation planes.

Near the Moine thrust-plane cataclastic structures are of frequent occurrence in the schistose rocks. It has been further proved that, near this line of displacement, rocks of diverse age and origin have acquired a common type of structure under the influence of post-Cambrian movements, and that in the case of the Torridonian sediments true crystalline schists have been simulated, if not actually produced. On the other hand, it has been shown that the structures of the siliceous Moine schists have been broken down near the Moine thrust-plane, thus indicating that some of these rocks existed as crystalline schists before they had reached their present position.

In central Ross-shire evidence has been obtained by the Geological Survey pointing to the manufacture of crystalline gneisses and schists out of igneous and sedimentary rocks by dynamic metamorphism. In that region, the Moine rocks are pierced by masses of augen gneiss, ægirine-riebeckite-gneiss hornblende-gneisses and schists, which, in places, are nearly free from foliation and possess their original igneous structures. These igneous intrusions are surrounded by an aureole of banded hornfelses which show contact metamorphism. They contain garnet, sillimanite, and pseudomorphs of andalusite. The bedding planes of these sediments are clearly preserved. Originally they were evidently finely laminated arenaceous shales an inference that has been confirmed by chemical analysis. Outside the aureole of hornfelsed rocks the normal psammitic and pelitic schists of the Moine series are typically developed. The detailed mapping of the region has revealed the various stages in the manufacture of schists and gneisses out of these igneous and sedimentary rocks by the processes resulting from earth movements. The age of these rocks and the periods of movement that produced the foliation have not been definitely determined.

In the eastern Highland belt, ranging from the counties of Banff and Aberdeen, through Perthshire to Argyll, the Moine series is replaced by metamorphic rocks, undoubtedly of sedimentary origin, which have been termed the Dalradian series by Sir A. GEIKIE. By the officers of the Geological Survey and other observers they have been divided into certain lithological groups that have been traced more or less continuously from Banffshire and Aberdeenshire to Kintyre. As the oberver passes northwards from the Highland border to the crest of the Grampians there is an apparent order of superposition in these groups. They include schistose grits and slates, Green Beds, mica-schists, graphite-schists, limestones and quartzites. In this direction also there is a gradual increase in the grade of metamorphism. Contemporaneous volcanic rocks (pillow-lavas, tuffs, and agglomerates) are intercalated in the Dalradian series in Argyllshire. Before planes of schistosity were developed in these Dalradian strata they were pierced by intrusive sheets of basic igneous rock (gabbro and epidiorite) and acid material (granite) which have shared in the movements that affected these schists.

Notwithstanding the extremely detailed mapping of the Geological Survey, the age of these sedimentary rocks, the original sequence of deposition, and their structural relations have not been satisfactorily determined. No theory has yet been advanced to explain the order of succession and the tectonics of the region which does not present obvious difficulties. One of the most recent interpretations (E. B. BAILEY'S) involves great recumbent folds with horizontal displacements of the rock groups extending for several miles in the county of Argyll. But the order of succession and the tectonics involved in this interpretation have recently been questioned by one of Mr. Bailey's colleagues in the Geological Survey (Mr. CARRUTHERS) who has mapped part of that complicated region.

An important advance has been made within the last few years in connection with the series of rocks at the eastern border of the Highlands near the Highland boundary fault. In that region this series consists of sheared spilitic lavas and intrusive igneous rocks with black shales, cherts and jaspers which, as shown by Mr. BARROW, are covered unconformably by a group of sediments termed by him the Margie series. At Stonehaven and Aberfoyle they have yielded fossils, including hingeless brachiopods, phyllocarid crustacea, worm-tubes, the jaws and chetæ of annelids, radiolaria, and a graptolite. The fossils, so far, seem to prove that the strata containing them are of Upper Cambrian or Lower Ordovician age. At Stonehaven the fossiliferous chert and green schist series along the southern margin is covered unconformably by Downtonian rocks. In the North Esk section Mr. BARROW has detected a line of thrust between the Margie series and the Highland schists to the north. In the Aberfoyle region the officers of the Geological Survey have not been able to locate this thrust in a satisfactory manner.

To the above account by Dr. HORNE I may add that Mr. BARROW's views differ in some respects from those held by his colleagues. He agrees that the Lewisian gneiss of the Northwestern region and the gneiss of the reputed "inliers" in the Highland complex are the same. There are two main "inliers" and these form with the Northwestern mass portions of three huge lenticles of thermo-metamorphosed sediments with igneous intrusions. These lenticles, according to him, can be mapped out into zones of higher and lower-level thermal alteration, which differ from those met with round a post-Torridon granite, partly in the minerals produced but chiefly in the form and size of the zones. He therefore forms the opinion that the masses of gneiss in the Highland complex fall into their proper places in the zoning of the lenticle as a whole, and cannot be described as "inliers."

When overthrusting came into operation, these lenticles snapped along their unaltered margins more readily than in their more crystalline parts, and it thus happened that along the Moine thrust the unaltered margin of the second lenticle was driven on to a highly crystalline part of the first lenticle, this latter constituting the "Lewisian gneiss."[1]

In view of the divergence of opinion which exists in spite of prolonged and detailed field work, I am forced to conclude that but little help can be expected from the Highland complex towards solving the problems of succession and correlation in the Pre-Cambrian rocks. Beyond the fact that the Torridon sandstone presents a lithological resemblance to some of the rocks to be referred to later, we have one clue only to a correlation of the Scottish and English developments. Certain pebbles of felsite occur in the Torridon series. They must "have been derived from a still earlier formation, of which no other trace has been found in the northwest of Scotland. They are identical in all essential respects with the felsites belonging to the Uriconian series of Shropshire."[2]

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[1] Proc. Geol. Assoc., Vol. XXIII, 1912, Pt. 5, pp. 265-290. With map showing the thermo-zoning of the South Eastern Highlands.

[2] J. J. H. TEALL in "*The Geological Structure of the North West Highlands of Scotland*," (Mem. Geol. Survey). 1907, p. 283.

II. IRELAND.

In the northern and northwestern parts of Ireland there is exhibited what appears to be a continuation of the Pre-Cambrian rocks of Scotland. The Lewisian gneiss can be closely matched in certain areas, while a wide-spread group of limestones, quartzites, phyllites and mica-schists with epidiorites and granite, known collectively as the Lough Foyle series, correspond in character to some of the sedimentary rocks of the Highland complex. The relations, however, of the Lough Foyle series to the gneiss have not been determined.

A small tract of schists and granitic rocks at Carnsore Point is also believed to be of Pre-Cambrian age.

III. ENGLAND AND WALES.

For the following note on Anglesey I am indebted to Mr. GREENLY who has been for some years engaged on a detailed survey of the island. The detailed results of Mr. Greenly's survey are in preparation for publication.

That a large part of the schistose complex of Anglesey is of Pre-Cambrian age can be inferred from indirect evidence, but more especially from two facts. A small outlier of rocks which are almost certainly of Cambrian age, rests unconformably upon the ancient schists; while secondly, on the adjacent mainland, near Bethesda, some conglomerates and grits, which are proved to be low down in the Cambrian succession by the fact of their lying far below slates with *Conocoryphe viola*, contain pebbles of various rocks derived from the complex, some of which are foliated. But, at the same time, it is possible that some rocks of later date, disguised by post-Silurian movements, have escaped detection, and are still wrongly left in the complex.

The only correlation with Pre-Cambrian rocks of other parts of the British Isles that can be made with confidence is with those of the Lleyn peninsula in North Wales.

The complex includes a great variety of rocks, both sedimentary and igneous, and in varying states of metamorphism. There are quartzites, schistose grits, clastic mica-schists, and phyllites, as well as mica-schists after acid igneous rocks and volcanic tuffs. A group of pillowy lavas, with limestones, and with jaspers that may safely be regarded as altered radiolarian cherts, is an important member. There are hornblende-schists and glaucophane-schists; and lastly, a group of deep-seated rocks, granites, diorites, and acid and basic gneisses. The whole is powerfully folded and disrupted, both on the small scale and the large, and the structures are extremely complicated.

The Longmynd.—This is one of a number of small disconnected areas in which rocks proved or inferred to be of Pre-Cambrian age are exposed to view. The Longmyndian series includes unaltered grits, shales and conglomerates, in part of a grey or purple tint, which present some resemblance to the Torridonian of Scotland. The series is demonstrably older than the Ordovician, and cannot be assigned to any part of the Cambrian. While the inference that it is of Pre-Cambrian age is strong, a correlation with the Torridonian is not capable of proof.

The Wrekin.—The basal Cambrian quartzite here unconformably overlies a series of unaltered andesites, rhyolites, basic lavas and intrusions, with tuffs and occasional conglomerates and shales. The relation of this series to the Longmyndian sediments is unknown. Here, therefore, again a local name (Uriconian) is the most suitable. There are several other small exposures of these rocks near the Welsh border, but they throw no light on the succession or correlation.

The Malvern Hills.—A plutonic complex, locally schistose and foliated, here forms the floor upon which the Hollybush sandstone (Lower Cambrian) rests unconformably. The sandstone contains rolled fragments of the underlying rock.

Barnt Green (Worcestershire).—In this small inlier of about one-eighth of a square mile, there are seen shales and quartzites of green grey and purple colours. Fragments of felsite, and of crystals of feldspar occur in the coarser bands, and some of the finer bands are likely to be tuffs. Some pink rhyolitic bands may be intrusions or silicified volcanic dust. The area is traversed by one or more dykes of diorite.

The rocks described above are faulted against the Cambrian basal quartzite. Their Pre-Cambrian age, therefore, rests on no direct proof.

Caldecote (Warwickshire).—There occur here volcanic breccias, felsitic tuffs and grits with basic intrusions. Some of the fine-grained tuffs are arranged in bands of different tints and so compact as to break with a conchoidal fracture.

Upon these rests the basal Cambrian quartzite. There is no obvious want of parallelism between the two formations, but the lower part of the quartzite contains large rolled blocks of the volcanic series. This fact and the contrast in lithological character lends support to the view that the Caldecote volcanic rocks are of Pre-Cambrian age. They may possibly correspond to the Barnt Green series, but cannot be paralleled with the Charnwood rocks.

Charnwood Forest (Leicestershire). The ancient rocks of this tract are surrounded by Keuper Marl. Their age therefore can only be inferred. They include the following subdivisions in descending order:

Brand series	Slates. Conglomerate, grit and quartzite. Purple and green beds.
Maplewell series	Olive-coloured hornstones. Hornstones and volcanic grits. Slate-agglomerate. Hornstones. Felsitic agglomerate.

Blackbrook series—Hornstones and volcanic grits.

The intrusive igneous rocks include porphyroids and augite-syenite.

It is generally assumed that all these series are of Pre-Cambrian age;

they cannot be matched in any Cambrian or post-Cambrian formation but the Brand series contains many individual bands like those of the Longmynd, while some of the grits and conglomerates are reminiscent of the Torridonian. On the other hand, none of the series are comparable with the Pre-Cambrian rocks of Caldecote, Barnt Green or the Wrekin.

In view of the uncertainty of correlation with other British occurrences, the group is named as a whole the Charnian system, and regarded as being of unascertained position in the Pre-Cambrian sequence.

The Lizard. The rocks for which a Pre-Cambrian age has been claimed with some doubt, include hornblende- and mica-schists, gabbro and serpentine, with granite and granitic gneisses, augite-syenite, dolerite, epidiorites. The oldest rocks in the neighbourhood of which the age is known, are assignable to the Ordovician.

St. Davids (Pembrokeshire). For the following note on the Pre-Cambrian rocks of Pembrokeshire I am indebted to Mr. H. H. Thomas, Petrographer to the Geological Survey.

Near St. Davids Pre-Cambrian rocks occupy a considerable area and consist of a great group of bedded rhyolitic and keratophyric tuffs, andesitic tuffs, conglomerates, halleflinta, and porcellanite. These are cut by intrusions of granophyric soda-granite and quartz-porphyry, and the whole is unconformably overlain by the Cambrian basal conglomerate and quartzite.

The bedded series was originally divided into two groups, Pebidian and Arvonian, but the Arvonian has been found to include rocks of post-Cambrian age and the remainder has proved inseparable from the Pebidian, which group now stands alone. For the intrusive rocks the name Dimetian was originally applied and has been retained.

The Pebidian of St. Davids has been found capable of subdivision according to age into the following series arranged in descending order:

Ramsey Sound series.	Rhyolitic tuffs.
Caerbwdy series.	Rhyolitic tuffs and halleflinta.
Treginnis series.	Andesitic tuffs.
Penrhiw series.	Red and green tuffs.

About eight miles to the east of St. Davids another mass of Pre-Cambrian rocks comes to the surface at and near Hayscastle. They consist of a bedded series of rhyolitic and keratophyric tuffs and lavas with subordinate andesitic tuffs, cut by intrusive masses of soda-granite and quartz-porphyry. Both the bedded and intrusive rocks are overlain unconformably by the Cambrian basal conglomerate and quartzite.

In the bedded series (Pebidian) two divisions have been established, the Pont-y-hafod group and the Rhindaston and Gignog group, which it is possible in a general way to correlate with the Treginnis, Caerbwdy and possibly Ramsey Sound series of the St. Davids area.

The Dimetian rocks with the exception of the diorite are practically identical with those of St. Davids; like them they show hardly any signs of foliation and may be referred with certainty to the same period of intrusion.

In southern Pembrokeshire a mass of igneous rocks, overlain unconformably by Upper Llandovery sediments, is inferred from its general characters to be of Pre-Cambrian age. It consists of a series of soda-rich volcanic rocks, mainly rhyolites, breccias and tuffs, to which the name Benton series has been applied, and a plutonic and hypabyssal series (Johnston series) intruded in the following order: Quartz-diorites, quartz-albite rocks and quartz-dolerites.

These two series differ somewhat in type from the Pebidian and Dimetian of St. Davids, and their relations to those groups are not known.

It is impossible to correlate, even in a general manner, the Pre-Cambrian rocks of Pembrokeshire with those of other British areas, even with those comparatively close at hand.

On summarizing the notes given in the preceding pages we find that the Pre-Cambrian rocks of the British Isles may be grouped under four different types, but that the relative age of the types has seldom been determined.

1. Gneissose rocks ("Lewisian gneiss") in Scotland and Ireland.

2. Metamorphic series of sedimentary and igneous rocks in Scotland ("Moine schists"), in Ireland ("Lough Foyle series"), in Anglesey ("Anglesey complex"), and, doubtfully, in Cornwall.

3. Unaltered volcanic or plutonic rocks in the Wrekin ("Uriconian"), in the Malvern ("Malvernian"), Warwickshire ("Caldecote series"), South Wales ("Pebidian").

4. Unaltered sedimentary rocks in Scotland ("Torridonian"), in the Longmynd ("Longmyndian"), at Barnt Green and in Leicestershire ("Charnian").

In one case only has a definite relation been established between any two types, namely in the superposition of the Torridonian upon the Lewisian gneiss in Scotland. It is suggested, but it has not been proved, that the Charnian and Longmyndian are correlative with the Torridonian and that the Uriconian are earlier. It has not been proved that the Uriconian, Caldecote series and Pebidian are correlative. Lastly the relative ages of the metamorphic rocks of Scotland, Ireland, North Wales and the Lizard are not only open to doubt, but the relations of the Moine schists to the Lewisian gneiss are not agreed upon.

Under these circumstances we seem to lack justification for attempting a chronological sequence of Pre-Cambrian rocks in the British Isles, further than is involved in placing the Lewisian gneiss among the oldest, and the Torridonian among the later formations. Thus far, the evidence is in accordance with the correlation of Torridonian with Keweenawan, and to a certain extent justifies a comparison of the Lewisian gneiss with the Laurentian of Canada.

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A STANDARD SCALE FOR THE PRE-CAMBRIAN ROCKS OF NORTH AMERICA.

BY

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Any attempt to formulate a general subdivision of the Pre-Cambrian involves the discovery of a particular region in which there is a maximum representation of rock formations, sedimentary, volcanic and plutonic, and in which, therefore, we may erect a standard sequence. It may well be that the sequence is incomplete, and that a large part of the geological record is written in terms of erosion rather than in terms of rock formation; but this does not relieve us of the necessity of erecting the standard and using it as a scale of reference. For it is only by so doing that we may hope to cure the defects in the local standard and so arrive at a closer approximation to the general sequence of events in Pre-Cambrian time.

A search for more than sixty years has failed to discover, so far as North America is concerned, any region more favourable for the purpose of establishing a tentative standard than that generally known, but vaguely defined, as the Lake Superior region. All students of Pre-Cambrian geology are more or less conversant with this region, either directly or through the medium of the literature describing it. In the past it has been a fruitful field, yielding much to our knowledge of the early history of the earth. There is a greater number of large groups of Pre-Cambrian rocks, the sequential and other relations of which can be made out, than in any other known region of the continent. The accessibility of the region and the excellence of its exposures render it probable that it will continue to be the classic field for the solution of the larger problems of Pre-Cambrian geology as they are presented in the structure of the North American continent.

There is but one drawback to the selection of the Lake Superior region as the one in which the tentative Pre-Cambrian standard should be established, and that is our lack of knowledge of the base of the Cambrian within its confines. In descending the Palæozoic sequence, our positive knowledge ends with the base of the Upper Cambrian; and this leaves room for the possibility that certain little altered and little disturbed formations, which are commonly regarded as Pre-Cambrian, may be, in reality, the equivalent of the lower divisions of the Cambrian. This, however, is a minor objection, since the chief interest attaches to the vast complex of still older rocks properly embraced in the Archæan. For the purposes of this paper, the current assumption that the Keweenawan and Animikie are of Pre-Cambrian age will be adopted.

As a point of departure for this discussion, we may take the classification of the Pre-Cambrian rocks of the Lake Superior region as agreed upon in December, 1904, by an International Committee consisting of ADAMS, BELL, LANE, LEITH, MILLER, and VAN HISE (chairman).[1]

The following succession and nomenclature were recognized and adopted by the Committee:

CAMBRIAN—Upper sandstones, etc., of Lake Superior.

Unconformity.

PRE-CAMBRIAN.

Keweenawan (Nipigon).

Unconformity.

Huronian:
- Upper (Animikie).
- *Unconformity.*
- Middle.
- *Unconformity.*
- Lower.

Unconformity.

Keewatin.

Eruptive contact.

Laurentian.

This scheme of nine years ago is to-day inadequate as a scale of the Pre-Cambrian rocks, and tends in some important respects to obscure rather than to elucidate geological history. It is the purpose of this paper to point out how it may be so enlarged and improved as to bring it in accord with existing knowledge. This may be done most conveniently by first giving the amended scheme and then presenting the argument in support of the changes suggested.

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[1] Jour. Geol., Vol. XIII, 1905, pp. 89-104. Also Rep. Bureau of Mines, Ontario, 1905, Vol. XIV, Pt. I, pp. 269-277.

Sequence and Classification of the Pre-Cambrian Rocks of the Lake Superior Region.

Upper Cambrian (Potsdam).

Unconformity.

Algonkian:
- Keweenawan (Nipigon).
- *Unconformity.*
- Animikie.

Eparchæan Interval.

ARCHÆAN:
- Algoman (granite-gneiss, batholithic in Huronian).
- *Irruptive contact.*
- Huronian:
  - Upper.
  - *Unconformity.*
  - Lower.
- *Unconformity.*
- Laurentian (granite-gneiss, batholithic in Ontarian).
- *Irruptive contact.*
- Ontarian:
  - Keewatin.
  - Coutchiching.

THE OLDEST ROCKS.

In my report on the geology of Rainy Lake region for 1887[1] I described a great series of metamorphic sedimentary rocks lying below the Keewatin and named it the Coutchiching series, from the rapids of that name at the outlet of Rainy lake, where these rocks are well exposed. The relative position of the Coutchiching and Keewatin was based chiefly on observations made on two well defined anticlinal structures; one in the vicinity of Bear's Passage and one on Rice bay, Rainy lake. The estimates of the maximum volume of the series, however, were based on the section afforded by the Canadian shore of the southeast expansion of the lake. Some years later, when the International Committee visited Rainy lake, it did not examine the Bear's Passage and Rice Bay sections, where the stratigraphic relations of the Coutchiching and Keewatin are well exposed, but confined its attention chiefly to the section across Shoal lake on Seine river. Here, owing to the rapidity with which the work was done, I fell into error in my report of 1887. This

[1] Geol. and Nat. Hist. Survey of Canada, Ann. Rep. 1887, Pt. F.

error was easily detected by the geologists of the International Committee and consisted in my failure to recognize that in the conglomerate of Shoal lake I had to deal with the base of a post-Keewatin series of rocks. The Committee concluded that the conglomerate was the base of the Coutchiching, and that the latter, therefore, lay unconformably upon the Keewatin. If the Committee had examined the Bear's Passage and Rice Bay sections, they probably would have reached another conclusion.

For the purpose of reviewing this question, I spent the field season of 1911 on Rainy lake and Seine river, and have reported the results of my studies to the Director of the Geological Survey of Canada, at whose suggestion they were undertaken. The report is accompanied by a geological map of that portion of Rainy lake which is critical for the question at issue. For the details of the observations the report and map[1] must be consulted, but the results may be summarized here.

In the vicinity of Bear's Passage, the Coutchiching rocks are prevailingly mica-schists, more or less distinctly stratified, which are disposed in a well defined anticline under particularly favourable conditions of exposure and accessibility. The axis of the anticline is on the line of the Canadian Northern railway, between mile-posts 209 and 210, and is also exposed on the adjacent shores of Redgut bay. Here the strata are nearly flat, but undulatory. Away from the axis, on either flank, the dip increases gradually, but more rapidly on the east than on the west, so that the anticline is not quite symmetrical. On the east flank, the strata pass beneath the Keewatin, and the actual contact is exposed in the cuts of the railway to the south of mile-post 208, the actual dip being about sixty degrees to the southeast. On the west flank of the anticline, the Coutchiching strata pass below the Keewatin rocks with a dip of from twenty to thirty degrees, and the actual contact can be located within a few feet. The overlying Keewatin rocks have similarly low dips. The dips refer to strata and not merely to schistosity. No geologist applying the ordinary principles of stratigraphy to this section can escape the conclusion that the Coutchiching rocks underlie the Keewatin and that this relation is due to the sequence of deposition.

The Rice Bay section is equally clear. Here the Coutchiching strata wrap around an intrusive mass of highly sheared granite, dipping away from it in all directions at angles usually of from forty to sixty-five degrees; and outside of this annular belt is an encircling belt of Keewatin lying upon the Coutchiching and dipping away from it. The relations of the two series of rocks are those stated in the report of 1887. The field work of 1911, while it amplified the evidence and improved the mapping, has in no way changed the conclusion reached twenty-five years ago, but has established it more firmly.

The belt of strata on Seine river with the Shoal Lake conglomerate at its base, which was referred partly to the Keewatin and partly to the Coutchiching on the map of 1887, belongs to neither of these series, but is later than

[1] *The Archæan Geology of Rainy Lake restudied:* Memoir No. 40, Geol. Survey of Canada

both and is the probable correlative of the Upper Huronian of the amended tabulation given above. It is part of a thick series of quartzites and slates with basal conglomerate which I followed eastward from the mouth of Seine river as far as Sabawe lake. Throughout this distance of seventy miles, these rocks have a persistent east-west strike and may be seen in unconformable relation to the Keewatin at numerous places. For the purpose of facilitating discussion I have used the local name, Seine series, for these rocks in the report above referred to.

The segregation of the Seine series from the Coutchiching and Keewatin as a probable correlative of the Upper Huronian (excluding Animikie from Huronian) clears the way for the better understanding of the relations of these two more ancient series. In view of the facts observable at the Bear's Passage and Rice Bay sections, as summarized above and more particularly recorded in the report of 1911, it is clear that in the standard Lake Superior section we must recognize a body of sediments, free, so far as at present known, from volcanic admixtures, which antedates and underlies the Keewatin. The most ancient rocks in the region are thus those of the Coutchiching series.

THE KEEWATIN SERIES.

The Keewatin rocks, which had been confounded with the Huronian prior to my work on Lake of the Woods, have in the past twenty-five years received a wide recognition as a persistent constituent of the pre-Huronian portion of the Archæan. They are composed chiefly of volcanic lavas, prevailingly basic and of the character of basalt and diabase, but also of acid quartz-porphyries and felsites. The basalts are very commonly ellipsoidal, and less commonly have a well marked amygdaloidal structure. Associated with these flows are tuffs and agglomerates in proportions so variable that they may be very prominent constituents of the series in some districts and almost or wholly lacking in others. Both the lavas and the pyroclastic rocks are sheared and schistified to a variable extent; so that in some districts they are very massive and in others highly schistose, in accordance with the deformation to which they have been subjected. In cases where the deformation has been acute it may be difficult to discriminate the coarser agglomerates from the ellipsoidal basalts. These basic lavas pass over into chlorite-schist and into hornblende-schist. The latter, usually in the form of a black, glistening rock, is characteristically found in the vicinity of the granite-gneisses which invade the Keewatin, and is probably a product of contact metamorphism. Besides these volcanic rocks there are various rocks of sedimentary origin such as slates, mica-schists, cherts and limestones which enter into the make-up of the Keewatin series.

In my report of 1887 on Rainy Lake region, I pointed out that the change in the conditions of rock formation which inaugurated the Keewatin does not in itself necessarily imply any great lapse of time between the cessation of the accumulation of the Coutchiching and the deposition of the first rocks of the Keewatin. But I suggested that the latter might be considered as unconformably related to the Coutchiching. This opinion, however, was based on a misconception of the stratigraphic position of the conglomerate of Rat-root bay, which has been shown in the report of 1911 to be the basal conglomerate of the Seine series. There is at present no evidence that the Coutchiching rocks were disturbed or subjected to erosion before the overflow of the Keewatin lavas upon them, except that in one section on Rainy lake there is evidence of the accumulation of land detritus between successive flows, indicating that, locally at least, the Keewatin lavas were not submarine flows and suggesting the emergence of the Coutchiching sea bottom.

ONTARIAN.

In 1889 I proposed[1] that the two series, Coutchiching and Keewatin, be together grouped as the *Ontarian system.* This suggestion has met with partial acceptance. The comprehensive term is needed not only to satisfy the requirements of complete classification, but is also a practical aid in facilitating the discussion of the relations of these two series to the Laurentian granite-gneisses. The latter are batholithic intrusions in both the Keewatin and the Coutchiching, and it is more convenient in many cases to refer to this plutonic activity as affecting the Ontarian than as affecting the Coutchiching and Keewatin. Its use will also simplify discussions involving broad correlations, as, for example, the correlation of the broad subdivisions of the Archæan of northern Europe with those of North America. For these reasons it is retained in the tabulation classifying the subdivisions of the Archæan.

LAURENTIAN.

Although the old notion of the metamorphic derivation of the Laurentian gneisses of the Lake Superior region from sediments has been entirely abandoned during the past twenty-five years, and they are now recognized as plutonic igneous rocks, the term itself has clung to them. This current practice was confirmed by the finding of the International Committee on Pre-Cambrian Nomenclature when, in 1904, it adopted the term Laurentian "for the granites and gneissoid granites which antedate, or protrude through the Keewatin, and which are pre-Huronian." Inasmuch as we have no certain knowledge of the existence of granites or granite-gneisses antedating the Keewatin, the term has come to mean those pre-Huronian granites and granite-gneisses which are intrusive into the Keewatin (or, in the Rainy Lake region, intrusive into the Ontarian). When pre-Ontarian granites and granite-gneisses are discovered they will, of course, receive a designation of their own which will distinguish them from the post-Ontarian or Laurentian rocks of the same type.

The significance of the term Laurentian as used in the Lake Superior region, and the position of the rocks to which it applies, are now sufficiently

[1] Bull. G. S. A., Vol. I, pp. 176-177.

well settled to render a detailed discussion unnecessary in this paper. It may be stated, however, in anticipation of what is to follow, that large and important areas of granite-gneiss which originated at a much later time, and which, therefore, do not conform to the definition above set forth, have been mapped and described in various reports and papers as Laurentian. This practice was recognized and sanctioned by the International Committee, when, in defining the term Laurentian, it stated: "In certain cases this term may also be employed, preferably with an explanatory phrase, for associated granites of large extent which cut the Huronian, or whose relations to the Huronian cannot be determined." By this the Committee referred to plutonic masses cutting the two lower divisions of the Huronian as they used that term, and did not intend to imply, I take it, that granites of large extent cut the Animikie. This practice of placing in the same division of the geological scale plutonic masses of both pre-Huronian and post-Huronian age has led to a confusion of ideas which should now be cleared up. In the standard Lake Superior section which it is the purpose of this paper to formulate, the term Laurentian is not applicable to post-Huronian rocks but only to those granite-gneisses and associated plutonic rocks which are post-Ontarian and pre-Huronian in age.

LOWER HURONIAN.

In addition to their occurrence as the lower division of the Huronian section, the Lower Huronian rocks have been recognized at several localities in the Lake Superior region. According to the latest general account[1] of the region by VAN HISE and LEITH, the series is represented in the Penokee-Gogebic, Marquette, Crystal Falls, Sturgeon River, Felch Mt., Calumet and Menominee districts on the south side of Lake Superior; and in all of these it consists of a basal conglomerate or quartzite and a formation of dolomitic limestone. In the Marquette district this limestone is overlaid by a formation of slates. In general, it rests in marked unconformity upon the Laurentian or Keewatin rocks. On the north side of Lake Superior the Lower Huronian has been identified only at Steeprock lake.[2]

On the shores of this lake there is exposed a series of strata which, in its lower part, at least, is remarkably similar to the Lower Huronian of the south side of Lake Superior. At the base is a thin conglomerate resting on the worn surface of the Laurentian, and this is followed gradationally by a thick formation of limestone. Above the limestone is a volcanic ash, and upon this rests a green schist holding an abundance of clastic quartz. The limestone is estimated to be from 500 to 700 feet thick, and contains fossils in great numbers, the prevailing forms of which have been described by WALCOTT.[3]

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[1] U. S. G. S. Monograph LII, 1911.

[2] For a brief account of the geology of Steeprock lake see "*Structural Geology of Steeprock Lake, Ontario,*" by H. L. SMYTH, Am. Jour. Sci., Vol. XLIII, 1891; also "*The Geology of Steeprock Lake, Ontario,*" by ANDREW C. LAWSON, Geol. Survey of Canada, Mem. No. 28, 1912.

[3] Geol. Survey of Canada, Mem. No. 28, 1912.

The Steeprock series is referred to the Lower Huronian, not only because of its resemblance to that series on the south side of Lake Superior, but also on the ground of order of succession, since it is very probably unconformably below the Seine series of the same district, which agrees well with the Upper Huronian.

The similarity of the Lower Huronian on the two sides of Lake Superior is significant of a widespread uniformity in the conditions of deposition. We must recognize a sea transgressing the eroded surface of the Laurentian rocks, in which littoral sediments gave place rapidly to the deposition of an extensive limestone formation; and the fossiliferous character of this limestone at Steeprock lake indicates that it was due to the abundance of lime-secreting organisms in the Lower Huronian sea.

The possible existence of Lower Huronian rocks at other localities on the north side of Lake Superior is indicated by VAN HISE and LEITH in their last monograph.[1] They refer to the Huronian of the Vermilion, Michipicoten, Mesabi, Gunflint and Loon Lake districts under the designation of "Lower-Middle Huronian," applying the term "Middle" to the series which in this paper is recognized as Upper Huronian. It is very doubtful, however, whether the Lower Huronian is really present in most of these sections. The Ogishke conglomerate, for example, is remarkably similar to the Seine conglomerate, which is at the base of the Upper Huronian.

But apart from these doubtful sections, we know enough of the Lower Huronian, not only in the type section on Lake Huron, but also at other localities in the Lake Superior region, to sustain the current opinion that the series is an important subdivision of the Pre-Cambrian, and to encourage the belief that its correlation in localities even widely separated can be established on the three-fold basis of: (1) lithological similarity, indicating uniformity of conditions of deposition in a wide sea; (2) stratigraphical sequence, having the Laurentian unconformably below and the Upper Huronian unconformably above; and, (3) the presence of a fossil fauna, an aid which, heretofore, had been scarcely hoped for in these rocks.

UPPER HURONIAN.

There are two unfortunate circumstances which tend to obscure the discussion of the systematic place of the Huronian rocks. One is that both of the major divisions of the Huronian should have the same name, distinguished only by the words, upper and lower. This infelicity is, at present, difficult to avoid, since both divisions were included in the original definition of the term Huronian, and geologists are loath to restrict the term to one or the other of the two modern divisions. It would, however, be a distinct simplification of our nomenclature and a great gain in the direction of clearness of ideas with regard to these ancient rocks if this restriction could be made.

The second circumstance referred to is the persistent effort which certain

[1] U. S. G. S. Mon. LII, 1911.

geologists of the U. S. Geological Survey make to include the Animikie in the Huronian under the designation Upper Huronian, although there is nothing in the original definition of the Huronian or in the type section of the Huronian, even in the comprehensive usage of the author of that term, with which it can possibly be correlated.

The history of the distension of the Huronian is interesting and illuminates the growth of our nomenclature. Prior to 1904, the geologists of the U. S. Geological Survey recognized in the Marquette region but two divisions of the Huronian, and these were known as the Upper and Lower Marquette. The Upper Marquette was correlated with the Animikie properly, and with the Upper Huronian erroneously. But an unconformity was discovered by SEAMAN in 1902 in the Lower Marquette, which led to the subdivision of the Marquette into the Upper, Middle and Lower Marquette and the correlation of the two lower divisions with the Upper and Lower Huronian of Lake Huron. This, of course, confirmed the objections that had been made by WILLMOTT[1] and myself[2] to the correlation of the Upper Marquette with the Upper Huronian of Lake Huron, and had the immediate effect of removing the Animikie (Upper Marquette) from the Huronian as the latter term had been understood by all geologists up to the year 1904.

But the Animikie and its equivalents on the south side of Lake Superior had been so long and so positively asserted to be Upper Huronian, that the geologists responsible for the error proceeded to distend the meaning of the term Huronian for the express purpose of including the Animikie and preserving the phraseology of their old and erroneous correlation, although the latter was definitely abandoned. There are only two divisions of the Huronian in the type section, but a third was created and the Huronian was divided into Upper, Middle and Lower Huronian. The Animikie and its equivalents, which, previous to 1904, had been correlated with what is, in this scheme, Middle Huronian, thus retained the designation of Upper Huronian, although the meaning of the term was totally changed. This curious and pathetic jugglery has been the main stumbling block to the proper understanding of the Lake Superior geology for the past nine years. That the International Committee in 1904 should have acquiesced in this remarkable procedure was a triumph of diplomacy for the geologists who proposed it; but advances in science are made along different lines. This distension of the Huronian so as to include the Animikie, and the subdivision of the term into Lower, Middle and Upper Huronian is a most embarrassing and confusing practice, regarded merely from the point of view of necessary discussion. Those geologists, and there are many, who recognize only two subdivisions of the original Huronian refer to these as Upper and Lower Huronian, and the term Upper Huronian has thus two quite distinct and conflicting meanings. This conflict has been so subversive of clarity of expression that it contributes a powerful argument in favor of the suggestion made above that the term Huronian should be restricted to one or the other of the two divisions of the

[1] Jour. Geol., Vol. X, No. 1.

[2] *The Eparchæan Interval*, Bull. Dept. Geol. Univ. Calif., Vol. III, No. 3, 1892.

type section on Lake Huron, and that a new name should be used for the other.

The Upper Huronian of the Lake Superior standard section embraces the formations above the unconformity at the base of the upper slate conglomerate, first discovered by ALEXANDER WINCHELL[1] in 1891, and more particularly defined by PUMPELLY and VAN HISE[2] in the year following, and their correlatives. These formations, in ascending order, are upper slate conglomerate, red quartzite, red jasper conglomerate, yellow chert and limestone. The correlatives in the more important localities are, according to the present consensus of opinion, as arranged in the following tabulation:

Correlation of the Upper Huronian in the Lake Superior Region.

Marquette, Dead River and Felch Lake districts.	Negaunee formation. Siamo slate. Ajibik quartzite.
Crystal Falls district.	Negaunee formation. Ajibik quartzite. Hemlock formation.
Menominee district.	Quartzite.
Mesabi district.	Ogishke conglomerate-slate-graywacke.
Vermilion district.	Knife Lake slates. Agawa formation. Ogishke conglomerate.
Rainy Lake district.	Seine series: conglomerate, quartzite, slate.
Steeprock Lake district.	Seine series: conglomerate, quartzite, slate.
Michipicoten district.	Doré conglomerate.

These correlations with the Upper Huronian are, of course, not so certain as in similar attempts in the Palæozoic and later divisions of the geological scale, since they are based on lithological similarities and stratigraphic sequence without the aid of fossils. Inasmuch as there is no dispute as to the

[1] Bull. G. S. A., Vol. II, 1891.
[2] Am. Jour. Sci., 3rd Ser., Vol. XLIII, 1892.

probability of the equivalence indicated, they may be regarded as fairly satisfactory, the existing differences of opinion having reference to the nomenclature rather than to the correlation itself. Most of the rock groups correlated with the Upper Huronian in the tabulation given above have been described in the literature dealing with Lake Superior geology, and an excellent summary of this knowledge is given in VAN HISE and LEITH's recent "*Geology of the Lake Superior Region;*"[1] but I have ventured to place the Ogishke conglomerate and associated strata of the Vermilion and Mesabi districts in the Upper Huronian rather than the Lower on the basis of the similarity of these rocks to the Seine series and their dissimilarity to the Steeprock series. A description of the Seine series is given in a forthcoming report of the Geological Survey of Canada.

ALGOMAN.

After the deposition of the Upper Huronian rocks the Lake Superior region was profoundly affected by plutonic activities resulting in the development of great granite batholiths similar to those of the Laurentian. These rocks were for many years supposed to be chronologically equivalent to the Laurentian granite-gneisses, which they closely resemble, both petrographically and in their contact relations with the rocks into which they are intrusive; and, therefore, they have been referred to as Laurentian in many reports and papers both in the United States and Canada. My recent (1911) re-study of the Rainy Lake region has shown that some plutonic masses which I mapped in 1887 as Laurentian, are in reality post-Huronian, being intrusive into the Seine series. Farther east in the Seine River country I was able to show that the granite-gneiss, which occupies the southeast quarter of the Seine River quadrangle and which has been mapped by the Geological Survey of Canada as Laurentian, is intrusive in the rocks of the Seine series (Upper Huronian). Splendid exposures demonstrating this relationship are to be seen on the line of the Canadian Northern railway near Iron Spur. A brief review of the recent literature of the Lake Superior region shows that several geologists have recorded similar facts. For example, the granite of the Giant's Range in northern Minnesota is described as intrusive in the Ogishke conglomerate and Knife Lake slates (Upper Huronian) of the Vermilion and Mesabi districts. This granite area has an exposed length of 125 miles and a width of twenty miles, and it is probably much more extensive below the formations which rest unconformably upon it.

An extensive area in north central Wisconsin, known as the Wausau district, appears to belong to this category of intrusives, if we accept the interpretation of the sequence given by VAN HISE and LEITH[2] rather than that of WEIDMANN.[3]

In the Baraboo district of Wisconsin, certain granites which have been

[1] U. S. G. S. Mon. LII, 1911.
[2] U. S. G. S. Mon. LII, pp. 355-358.
[3] Wis. Geol. and Nat. Hist. Survey, Bull. No. XVI, pp. 378-384, 1907.

regarded as Laurentian are also, on the same authority,[1] to be regarded as intrusive in the Upper Huronian. Similarly in the Loon Lake district, Ontario, granite which cuts the Upper Huronian (pre-Animikie) rocks is regarded by VAN HISE and LEITH[2] as the correlative of the Giant's Range granite. According to the mapping of the Geological Survey of Canada,[3] this post-Huronian granite of Loon lake is probably the same granite which I have described as intrusive in the Seine series (Upper Huronian) at Iron Spur on the line of the Canadian Northern railway.[4]

"To the north of Lake Huron, it is quite certain that the Huronian rocks rest on the eroded surface of the Laurentian and of the rocks into which the latter is intrusive. Yet it is equally clear from BARLOW's descriptions[5] that along the southeast border of the Huronian area there are granites and granite-gneisses which cut the Huronian.

WALKER[6] has described post-Huronian granite in the Sudbury district.

Similarly COLEMAN describes "coarse granites, and syenites, often porphyritic, which merge into gneisses and have been placed in the Laurentian by most writers" as intrusive in the Huronian of Sudbury district.[7]

The International Committee in 1904, recognized these post-Huronian granites. For, while restricting the term Laurentian to the pre-Huronian granites and gneissoid granites, it ruled: "In certain cases this term (Laurentian) may also be employed, preferably with an explanatory phrase, for associated granites of large extent which cut the Huronian, or whose relations to the Huronian cannot be determined."[8] This anomalous use of the term Laurentian was thus commented on by VAN HISE and LEITH[9] in 1909:

"A considerable part of the rocks mapped as 'Laurentian' is intrusive into the Algonkian (meaning Huronian; A. C. L.) but another large part is intrusive only into the Keewatin. 'Laurentian,' as used in the broad sense, becomes a catch-all for Pre-Cambrian (meaning pre-Animikie; A. C. L.) gneisses and granites of any area where structural relations have not been discriminated. There is danger that, unless the narrower and much more desirable application of the term recommended by the Committee be emphasized, the discrimination of the Archean and Algonkian (meaning pre-Huronian and post-Huronian) granites, so important for structural purposes, will be overlooked."

COLEMAN in his address to the Geological Section of the British Association for the Advancement of Science[10] discussed the question as follows:

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[1] U. S. G. S. Mon. LII, p. 360.
[2] U. S. G. S. Mon. LII, p. 206.
[3] Seine River and Lake Shebandowan sheets.
[4] Ante, p. 359.
[5] Am. Geol., Vol. VI, 1890, pp. 19-32. Am. Jour. Sci., 3rd Ser., Vol. XLIV, 1892, pp. 236-238. Bull. G. S. A., Vol. IV, 1893, pp. 313-332. Geol. Survey of Canada, Ann. Rep., Vol. XIV, Pt. H, 1901.
[6] Q. J. G. S. Vol. LIII, 1897, pp. 40-66.
[7] Rep. Bureau of Mines, Ontario, Vol. XIV, Pt. III, 1905.
[8] Jour. Geol., Vol. XIII, 1905, p. 103.
[9] U. S. G. S. Bull. 360, p. 28.
[10] Sheffield, 1910.

"At the end of the Keewatin the thousands of feet of volcanic and clastic rocks were lifted as domes by the upwelling of batholiths of early Laurentian gneiss. . . . During the Middle (*i.e.*, Upper) Huronian, or in the interval between it and the Upper Huronian (meaning Animikie; A. C. L.) mountain-making was renewed on a grand scale, many synclines of Keewatin and Lower Huronian rocks being caught between the rising batholiths of late Laurentian gneiss. . . . The granites and gneisses of this second time of mountain-building have not been distinguished in mapping from those of the first in most places; and as they are both of precisely the same habit, it will probably never be possible to separate them completely. Thus far, both have been included under the term Laurentian."

From the foregoing summary of observations, it is obvious that we have to deal with the products of two widely separated periods of plutonic activity in the earth's crust, one post-Ontarian and pre-Huronian, and the other post-Huronian and pre-Animikie. The rocks of both periods were at first confused and regarded as all belonging to the Laurentian. In later years, notwithstanding the gradual recognition of the distinctness and time interval between the two irruptive periods, the rocks of both continue to be called Laurentian. As long as this practice continues we shall never be able to clear up the problems of the Archæan; and the time has come when the second great period of batholithic development in the Lake Superior region must receive recognition not only in observational records but also in our nomenclature. In a report on the Rainy Lake region for the year 1911, submitted to the Director of the Geological Survey of Canada, I have proposed that this period be called the *Algoman*, from the old western Ontario district of Algoma, in which these plutonics are well displayed and widely distributed.

EPARCHÆAN INTERVAL.

It is customary in systematic geology to record the divisions of geological time in terms of sedimentation or of rock formation rather than in terms of degradation. This practice is, of course, justified by the belief which prevails among geologists that unconformities representing periods of degradation are rarely, if ever, universal in the geographical sense, and that the time consumed in degradation in one region is represented by the sediments which have accumulated in another, so that, if the geological scale be based upon a sufficiently large portion of the earth's crust, all geological time will be accounted for. In certain cases, however, in which we have to deal with very large unconformities of vast extent, it is clear that a scale consisting of an enumeration of rock groups in chronological sequence does not adequately subdivide geological time. Large divisions of time, exceeding in value the periods represented by accumulations of rock are thus lost sight of or are slurred over without due appreciation of their importance. Such a period is that which elapsed between the intrusion of the Algoman batholiths into the Huronian and pre-Huronian rock and the deposition of the Animikie. We must agree with Coleman in regarding the post-Huronian batholithic development, which certainly extended on both sides of Lake Superior from Rainy lake to Lake Wanapitei and probably much farther, as a period of mountain-making movements. The resulting mountains were entirely swept away, the batholiths were deeply exposed, and a region of continental extent was reduced to a peneplain before it was depressed to receive the Animikie sediments. This peneplain is now fully recognized by VAN HISE and LEITH. They say: "The Upper Huronian (Animikie) was deposited on a remarkably uniform peneplain. Remnants of this peneplain appear from beneath the Upper Huronian in the Mesabi, Animikie, and Gogebic districts."[1] They amplify this statement in the following words: "The Upper Huronian (Animikie) rests upon a flat plane, bevelling alike hard and soft, resistant and non-resistant rocks without residual or terrestrial deposits at the base."[2]

These statements confirm the views that I expressed eleven years ago as to the magnitude and taxonomic importance of the pre-Animikie erosion interval, which I then designated as the Eparchæan Interval.[3] I pointed out at that time that we have no knowledge of any sediments laid down elsewhere in that interval, and that it is not represented in the nomenclature of the geological time scale. I argued then, and still hold it to be true, that to class rocks on both sides of this interval in the same category under the same designation is unscientific and inconsistent with geological practice. It obscures a great fact in geological history, although the purpose of our nomenclature should be to elucidate that history. The distension of the Huronian so as to include formations on both sides of this vast interval not only obscures the history of the region but involves the correlation of a well defined series, the Animikie, with a division of the Huronian which has no existence in the type Huronian area; it involves a substitution of the term Algonkian for the earlier, well established term, Huronian; and it involves the over-throw of the term Archæan as it was defined by DANA and almost universally accepted. I am, therefore, of the opinion to-day, more strongly than ever, that the bridging of what I have called the Eparchæan Interval by the Huronian is bad in principle, is bad practice, and grossly violates the rule of priority in nomenclature.[4] This vicious scheme might possibly be condoned if there were any compensating practical gain proceeding from it. But I know of none, unless, indeed, it be that it covers up the errors of correlation that were in vogue on the south side of Lake Superior prior to 1904.

It may be urged that in some of the early reports and maps of the Geological Survey of Canada the Animikie and Keweenawan were regarded as the correlatives of the Huronian of Lake Huron. This was, however,

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[1] U. S. G. S. Mon. LII, p. 610.

[2] Id., p. 612.

[3] Bull. Dep. Geol. Univ. Cal., Vol. III, No. 3, 1902.

[4] In this connection DANA, (*Manual of Geology*, 4th ed., 1896, p. 447) says: "The Algonkian formation is made by its describers to include the Huronian of Logan, north and south of the lakes, and some of the so-called Huronian in other regions. . . . The supplanting of the older name, Huronian, by the newer is not sustained by any rules of nomenclature."

an error in correlation and has long since been corrected.[1] It was the same error that the geologists of the south side of Lake Superior persisted in, with less excuse, up to 1904. They also have corrected their mistake; but neither their error nor LOGAN's is a warrant for correlating the Animikie with a third division of the Huronian which has no existence in fact.

Another consideration has been urged, not against the recognition of the Eparchæan Interval, but rather against signalizing it by a special designation. This is that the pre-Huronian unconformity is equally profound. This may be conceded without argument. There can be no doubt of the fact that the interval which elapsed between the development of the Laurentian batholiths and the deposition of the Lower Huronian sediments is comparable to that which elapsed between the development of the Algoman batholiths and the deposition of the Animikie. So long as we have no known record of sedimentation elsewhere for this interval, our scale will be incomplete in that a large period of geological time is unnamed. Since the recognition of the Keewatin, no attempt has been made to slur over this gap, but, on the contrary, the tendency has been to accentuate it; and the free recognition of its importance has in a large measure obviated the necessity of signalizing it by a special name. In the interest of complete taxonomy, however, it should be so signalized, and I suggest that Epi-Laurentian Interval be applied to this period of geological time.

ARCHÆAN.

The term Archæan is retained in the proposed standard scale of the Pre-Cambrian of Lake Superior in the sense in which DANA first used it, and in which it received wide acceptance, including the Huronian and older rocks.[2] This definition was stable until 1889, when the U. S. Geological Survey undertook to change it without regard to the views of geologists not members of its staff. It then ruled:[3] "The oldest time division shall cover the time of formation of the ancient crystalline rocks, and its designation shall be the Archaean." To understand the significance of this, it is necessary to quote another ruling from the same page: "the tenth period shall be the time of deposition of clastic rocks older than the Cambrian. . . . The term Algonkian was offered and agreed to as the designation of the period." By this offering and agreement (observe the naive effrontery of the process!) the Archaean was stripped of all its clastic rocks, and, as the new creation was in dire need of habiliments to cover its nakedness, they were generously handed over to the Algonkian, poor thing! Thus were the formations of the Grenville series, the Hastings series, the Coutchiching series, the Huronian series and all other pre-Animikie series that had anything clastic in their make-up taken from the Archæan. The Keewatin was left in because it

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[1] In the comprehensive report of 1863, p. 67, the rocks now known as Animikie were declared to be younger than the Huronian.

[2] *Manual of Geology*, 3rd ed., 1874, p. 151. Also, Am. Jour. Sci., 3rd Ser., Vol. VIII, 1874, p. 213.

[3] U. S. G. S. 10th Ann. Rep., Pt. I, p. 66, 1890.

was incredible to these manipulators of geological history that it could be tainted with clastic admixtures. The rules of nomenclature that give stability to our science were thrown to the winds. What rules, forsooth, should stand in the way when poor little Algonkian needed sedimentary formations?

It took the U. S. Geological Survey about twelve years to discover that this rape of the Archæan was a blunder; that it was the expression of a theory for which there were no corresponding facts. The theory has been abandoned now for ten years or more; but the blight of the offering and agreement still lingers. In its bloom the term Archæan was restricted to Keewatin and Laurentian, and the restriction is still persisted in. What is now the excuse for withholding the Huronian from the Archæan? Who has the right to overthrow the established nomenclature without the acquiescence of all concerned? What does our science gain by such buccaneering tactics? In what respect is Huronian better, classed under Algonkian than under Archæan? Why should we pauperize the Archæan of DANA to glorify the Algonkian of VAN HISE?

The only excuse that ever existed for the erection of the Algonkian was the recognition of a group of rocks below the Cambrian and above the Archæan. In the Lake Superior region, that group consists of the Animikie and the Keweenawan. The upper limits of that group are not well defined. It is not certain that the group does not represent the two lower divisions of the Cambrian. The lower limit is, however, clear and positive. The Animikie rocks were laid down on the surface of a vast and remarkably uniform peneplain. That peneplain was worn across the upturned edge of the Archæan as it was defined by DANA and universally understood up to the time when the remarkable offering and agreement were made. That Archæan included the Huronian; so that the proposition to establish a subdivision of the geological column between the Cambrian and Archæan in the Lake Superior region could not include more than the Animikie and Keweenawan so long as the usual respect was paid to the existing nomenclature and the rights of geologists using it.

Unfortunately, the geologists of the south side of Lake Superior, from IRVING on, laboured under a misapprehension as to the correlation of the Animikie. IRVING, in his paper on the classification of the early Cambrian and Pre-Cambrian formations[1] correlated the Animikie with the "original or type Huronian." This error, as I have already shown, was persisted in by the U. S. geologists till 1904, when, in consequence of SEAMAN'S work, they discovered that the Animikie and its equivalents of the south shore (Upper Marquette, etc.) were not the correlatives of any part of the "original or type Huronian." There can be no doubt but that IRVING and his successors were greatly impressed by the discreteness of the Animikie rocks on both sides of Lake Superior from the typical Archæan rocks of the region, and that they were influenced by the contrast, coupled with the mistaken corre-

[1] U. S. G. S. Seventh Ann. Rep., 1885-6.

lation, in proposing to take the Huronian out of the Archæan and place it in the Agnotozoic, for which term Algonkian was later substituted. The relation of the Huronian to the granites and granite-gneisses of the Algoman period were not understood. These plutonic rocks are very similar to those of the Laurentian, and were classed with the latter as belonging unconformably below the Huronian. This error served as the basis of IRVING's argument that the Archæan should be restricted to the pre-Huronian rocks, because these represented a condition in the development of the earth's crust which was peculiar to that early time and had never recurred. The argument still holds in large measure, but it places the Huronian in the Archæan, since it is now certain that a large part, perhaps the greater part, of the rocks which IRVING regarded as Laurentian are post-Huronian in age. On the far side of the Eparchæan Interval, there is recorded in the rocks of the Lake Superior region a history of plutonic activity which has not recurred since. I refer to the great granite batholiths of the Laurentian and the Algoman periods. Until recent years it has been supposed very generally that this batholithic development was peculiar to the Laurentian. If this were so, there might be the justification of expediency in separating, as Archæan, the rocks evolved from and involved in this remarkable plutonic activity from later rocks not so affected. But it is now clear that these plutonic forces were recurrent in their operation and that there was another great development of batholiths in post-Huronian time. These granites of the Algoman period traverse the Huronian and all other older rocks of the region, knitting them together in a vast complex; and it is to this complex that the term Archæan, not only historically but logically, applies. It is true, as IRVING argued, that there are remarkable and peculiar conditions of crustal development which characterized Archæan time and which have not recurred in later time; but, if a large part of these conditions are of post-Huronian age, then surely, according to the argument, the Huronian must remain in the Archæan.

By way of summary, the reasons for leaving DANA's definition of Archæan intact may be listed:

1. The Animikie is not the correlative of any part of the original or type Huronian.

2. The Huronian rocks antedate the extensively developed granites and granite-gneisses of the Algoman period of plutonic activity.

3. The Animikie rests upon a remarkably uniform peneplain worn not only out of the Huronian rocks but also out of the post-Huronian or Algoman plutonics.

4. The batholithic development which characterized the Laurentian and Algoman periods indicates that the conditions of crustal evolution which prevailed on the far side of the Eparchæan Interval were different from those which have prevailed on the near side.

5. The intrusion of the Algoman batholiths into the Huronian and older rocks serves to knit them together in a complex having a general individuality for which a common comprehensive term is needed. Archæan serves this purpose well.

6. The rulings of the U. S. Geological Survey definitive of Archæan and Algonkian[1] have been reversed, the hypothesis which served as the motive for them has been abandoned, and the subdivision of the Archæan formulated in these rulings has now no theoretical excuse.

7. The classification based on this abandoned hypothesis has been persisted in apparently for the sole purpose of saving the term Algonkian as the designation of a system, although no stratigraphic relationships are thereby brought out which give a more natural grouping or a clearer understanding of geological history than the classification which it seeks to displace; and important relationships are obscured by the disintegration of the fundamental complex—DANA's Archæan—on the one hand and the bridging of the Eparchæan Interval on the other.

These considerations have to do with the merits of the question and are apart from those which flow from the rule of priority. Taken with the latter, they leave no excuse for changing the established meaning of the term Archæan on the ground of propriety, expediency or scientific argument.

ANIMIKIE.

The Animikie series of the Lake Superior region is so well known and the correlation with its equivalents on the south side of the lake is so satisfactory that little further need be said in this place to justify its position in the standard scale. The series represents a well defined period of sedimentation and consists chiefly of quartzite, impure iron carbonates, cherts and carbonaceous shales. These, on the north side of Lake Superior, are free from volcanic admixtures, but volcanic rocks on the south side of the lake have been described[2] as constituent members of the series in Marquette district; and similar admixtures are stated to occur in the Animikie of other districts, although in most cases there appears to be some obscurity of the relations and suggestive similarities with the volcanic rocks of the Hemlock formation of the Upper Huronian (pre-Animikie). The important matter with regard to the Animikie from a taxonomic point of view is its entire distinctness from the Huronian and its position on the near side of the Eparchæan Interval as set forth in the foregoing discussion.

KEWEENAWAN (NIPIGON).

The Keweenawan series consists of volcanic and sedimentary rocks resting unconformably upon the Animikie or upon surfaces of older rocks from which the Animikie had very probably been stripped in post-Animikie time. It is not improbable that the sedimentary portions of the series are continental deposits and that they are, therefore, not indicative of submergence of the region during the time of their accumulation.[3] Besides the effusive lavas of the series, there is an enormous amount of intrusive material, chiefly

[1] U. S. G. S. 10th Ann. Rpt., Pt. 1, 1890, p. 66.
[2] U. S. G. S. Mon. XXVIII.
[3] U. S. G. S. Mon. LII, p. 416.

in the form of sills and dykes of basic rock, and many of these traverse the underlying Animikie. In certain notable instances these basic intrusions either have fused the sediments which they invaded, and so produced red, acid, aplitic rocks,[1] or have suffered acute magmatic differentiation,[2] affording gradations from acid to basic types. There are also larger masses of the character of chonoliths or stocks of granite, which cut the Keweenawan rocks; but these are quite different, as to dimensions, form and relations to the invaded rocks, from the great batholiths of the Laurentian and Algoman. One of the largest of these granite masses is the Embarrass granite of the Mesabi district described by Leith,[3] as intrusive in the Animikie. But the intrusion does not appear to have disturbed the attitude of the Animikie which lies flat upon it, with strata parallel to the contact. The proof of the fact of intrusion is not entirely satisfactory and the mapping does not indicate intrusive relations. There seems, similarly, to be inadequate proof of the statement[4] that granites cut the Animikie of the Florence district, Wisconsin.

ALGONKIAN.

The discussion of the previous pages definitive of the Huronian and Archæan necessarily limits the term Algonkian to the Pre-Cambrian rocks on the near side of the Eparchæan Interval, and these in the Lake Superior region are embraced in the Animikie and Keweenawan. These formations are much more closely related to the Palæozoic in time, in physical characteristics, and in their disturbance and metamorphism than to the Archæan complex. Whether the Algonkian should be regarded as a lower division of the Palæozoic or a major division of the geological scale co-ordinate with Palæozoic and Archæan is left an open question.

CLASSIFICATION AND CO-ORDINATION.

In the proposed standard scale of the Pre-Cambrian rocks of Lake Superior, of which this paper is an exposition, the sequence of rock groups and erosional intervals is for the most part unquestioned. Serious doubt has been cast upon the position of the Coutchiching, but my review[5] of that question in the field confirms my conclusion of twenty-five years ago that these are the oldest rocks of the region. The evidence upon which this conclusion is based is subject to verification in the proper geological sections, which are clearly set forth in the report of 1887 and more explicitly in the report of 1911. The Algoman is on the same basis as the Laurentian and merits the same recognition. It signalizes the fact that in post-Huronian time, anterior to the Eparchæan Interval there was a period of widespread plutonic activity analogous to that which produced the Laurentian batho-

[1] Bayley, U. S. G. S. Bull. 109, 1893.
[2] U. S. G. S. Mon. LII, p. 411.
[3] U. S. G. S. Mon. XLIII, 1903.
[4] U. S. G. S. Mon. LII, p. 609.
[5] Memoir No. 40, Geol. Survey of Canada.

liths at an earlier period. This fact has been observed in different parts of the region by various geologists, but its full significance appears not to have been appreciated; and the rocks of this period have been commonly confounded with those of the Laurentian. There thus appears to be ample justification for introducing this term into the geological standard scale.

Assuming that Coutchiching and Algoman are real rock groups having the place assigned to them in the time sequence, and that there is no doubt as to the existence and relative position of the other rock groups and erosional intervals, the only question that remains is that of classification and co-ordination. This, it may be claimed, is relatively unimportant; that the main purpose is attained when we have stated correctly the various formational groups and erosional intervals in their proper sequence; that this being done, we may proceed with our correlations and leave the questions of classification and co-ordination to a later time when our information shall be more complete. There would undoubtedly be a certain advantage in this procedure; but the interpretation of geological history has a fascination which few geologists can resist, and interpretation involves the attempt at classification and co-ordination. When a certain classification is proposed and is repeated over and over again in the literature it becomes an instrument of convenient expression for those who believe the interpretation which it implies, and an obstacle to expression for those who do not believe in that interpretation. All geologists concerned with the interpretation of geological history must assent to or dissent from the classification. For this reason it is extremely important that such classifications should be as free as possible from debatable hypotheses, such, for example, as questionable correlations. The old classification of the rocks of the Lake Superior region, as advocated by the geologists of the south side, involved the hypothesis that the Animikie is the correlative of the upper part of the type Huronian of Lake Huron. Reiteration of this hypothesis, stated as a fact, in numerous volumes through many years, caused the younger generation of geologists to believe it to be a fact. Animikie for a time became synonymous with Upper Huronian, and geologists who dissented from the correlation could not use the term Upper Huronian without grave danger of being entirely misunderstood. Finally, when this error was discovered in 1904, the term Upper Huronian was used in a totally different sense applicable to a set of rocks non-existent in the type Huronian section. Before 1904 Upper Huronian meant one thing, and after 1904 it meant something totally different to the geologists of the south side of Lake Superior; but both before and after that date it meant Animikie. It would have been much better to have used simply Animikie without the synonym Upper Huronian, especially as there is no question in any quarter as to the sequence, and there is no equivalent of the Animikie in the type Huronian.

The confusion engendered by these errors might have been avoided if such disputed correlations had not been made an essential part of the classification of the rocks of Lake Superior by the geologists of the south side of the lake.

The standard scale here proposed involves no disputed correlations. The sequence of formational groups and erosional intervals represents a consensus of opinion from which there is, I believe, no dissent, except in regard to Coutchiching and that is, as I have stated, subject to verification.

The main question in the classification of these formational groups is the dividing line between the Archæan and post-Archæan. I have already set forth the considerations which seem to me to settle the question, and there is no occasion to re-state them. But I desire to emphasize the fact that the classification is not merely a convenient grouping and arrangement, but that it is an interpretation of geological history. If we bridge the erosional gap which I have called the Eparchæan Interval by classing the formations on both sides of it as Algonkian *and* Huronian, that is one interpretation. It means that the interval is not sufficiently large and important to separate the Animikie and Huronian as distinct series widely spaced in time. It means the earth's crust over a continental region may be affected by mountain-making movements with the development of vast batholiths, that the mountain structures may be worn away, the batholiths deeply denuded and the whole region reduced to a remarkably uniform peneplain without our recognizing in these events a sufficient lapse of time to warrant the separation of the Animikie and Huronian into distinct series. It means the minimizing and slurring over of two great periods of geological history, one of plutonic activity and products—the Algoman, and one of prolonged erosion—the Eparchæan Interval.

If on the other hand we recognize the Eparchæan Interval as an important division of geological time separating the Archæan from the post-Archæan, that is an entirely different interpretation. It makes possible the recognition of the Algoman as a period and rock product co-ordinate with the Laurentian. It keeps all the rocks involved in these two great plutonic movements in the Archæan, and emphasizes the fact which IRVING sought to bring out, that certain conditions of crustal development prevailed on the far side of the Eparchæan Interval which were absent on the near side. It recognizes the individuality of the Archæan as a whole by the characteristics which have been imposed upon it by the two-fold recurrence of batholithic invasions. It recognizes the value and importance of great erosional intervals in dividing the geological scale. It completes the time scale by inserting in it a period of time the record of which is in terms of erosion not elsewhere represented, so far as we know, by sediments. Added to this, it satisfies our sense of justice in that it leaves the Huronian in the Archæan in the way that DANA defined it.

The Archæan is one of the major divisions of the geological scale. It is not a "system" co-ordinate with such subdivisions as the Devonian system, the Cretaceous system, etc., but is a division co-ordinate with Palæozoic, Mesozoic, etc. It embraces at least two systems of sedimentary and volcanic rocks in no way dissimilar in their original character and conditions of accumulation to the rocks of the Palæozoic. These are the Ontarian system and the Huronian system, and each of these is subdivisible into two series, the former comprising the Coutchiching and Keewatin series and the latter the Lower and Upper Huronian series. Besides these, the Archæan includes the vast batholiths of the Laurentian and Algoman periods, the importance of which as constituent parts of the earth's crust can scarcely be exaggerated. Such an assemblage of rocks cannot appropriately and consistently be coordinated with the individual systems of the Palæozoic, for to do so would imply an inadequate conception of the duration of Archæan time. It is quite possible that future investigations may bring to light formations older than the Ontarian, but, even as we now know it, the Archean far exceeds the Palæozoic in the volume of rocks entering into the make-up of the earth's crust over a continental region, so that upon this count, as well as upon the length of time involved, the term should be used for a major division of the scale. In brief, to call the Archæan a system is to put a false and absurdly inadequate interpretation upon this portion of geological history.

The Algonkian appears to be properly designated a system. It embraces two series, the Animikie and the Keweenawan. As it stands in the scale, it is a Pre-Cambrian system, intermediate in position between the Palæozoic and the Archæan. It is much more closely related to the former than to the latter. A logical classification would be to extend the Palæozoic downward so as to include it. It is customary, but by no means necessary, to regard the Cambrian as the lowest system of the Palæozoic. There can be no rational objection to placing the beginning of the Palæozoic at the end of the Eparchæan Interval. There may, however, be sentimental objections and the decision of the question may be left in abeyance.

THE ARCHÆAN AND PURANA GROUPS OF PENINSULAR INDIA.

BY

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When the work of the Geological Survey of India was first summarized by H. B. MEDLICOTT and W. T. BLANFORD[1] in 1879, WERNER's name *Transition* was used to cover the older of the unfossiliferous systems on the Peninsula, that is, those formations occupying a stratigraphical position between the undisturbed *Vindhyan system* above and the fundamental complex below, the latter being distinguished as the *Gneissic or Metamorphic group*.

The "Transitions" being recognized in various independent areas, received provisionally local names and were treated in two divisions. The *Upper* of these included the formations known by the local names of Gwalior, Cuddapah and Kaladgi, while the *Lower* division included the Champanirs, the Aravallis and what were afterwards distinguished as the Dharwars (see Table I).

TABLE I: MEDLICOTT and BLANFORD, 1879.

Palæozoic.

Azoic:	Vindhyan series:	*Upper* Vindhyans.
		Lower Vindhyans (Semri) and Kurnools.
	Transition or Sub-Metamorphic:	*Upper*, including Cuddapahs and Gwaliors.
		Lower, including Champanirs (= Dharwars).
	Metamorphic or Gneissic:	Gneiss, granitoid and schistose rocks.

In the second edition of the official Manual published in 1893, R. D. OLDHAM included in the Transitions all the formations previously referred to as the Lower Transitions, and to these he added the Gwaliors. The rest, that is, the Upper Transitions of MEDLICOTT and BLANFORD, were grouped with the Vindhyans as *Older Palæozoic* (see Table II).

[1] *Man. Geol. Ind.*, 1st Edition, 1879, pp. xiii, xix, 3, 26.

TABLE II: R. D. OLDHAM, 1893.

Older Palæozoic:	Vindhyan. Cuddapah.
Transition systems:	Dharwar, Champanir, etc.
Metamorphic and crystalline:	Gneiss, gneissose granite, schists, etc.

In 1906 the writer[1] proposed to recognize the dividing line between MEDLICOTT and BLANFORD's Upper and Lower Transitions as a main line of stratigraphical classification. The formations below this line are closely folded and generally foliated, while those above are but locally folded, are often almost flat-bedded and are generally unaltered. The latter formations in places rest on the upturned and denuded edges of the former, and the dividing line marks a great, and so far as peninsular India is concerned, a widespread unconformity. The close folding of the rocks below this datum line shows that there must have been a period of mountain formation on a grand scale, followed in the Indian region by a general degradation to a fairly uniform peneplain, on which were laid down great thicknesses of sediments and lava-flows akin in general characters to the Animikie and Keweenawan of North America (see Tables III and V).

TABLE III: T. H. HOLLAND, 1906.

Purana group:	*Upper* Cuddapahs, Vindhyans and Kurnools. *Lower* Cuddapahs, Gwaliors, etc.

Eparchæan Interval.

Archæan group:	Post-Dharwar eruptives. Dharwars. Deformed eruptives of the "Bundelkhand" (Laurentian) type. Schistose gneisses of the "Bengal" type. Oldest gneisses.

[1] T. H. HOLLAND, Presidential Address, Trans. Min. and Geol. Inst. Ind., Vol. I, 1906, p. 47.

This great unconformity is thus comparable to that referred to by Dr. A. C. LAWSON[1] as the *Eparchæan interval* in the region of the Great Lakes of North America. The objections urged by LAWSON against the use of a term like Algonkian or Huronian to straddle across such a great physical break apply also to the terminology formerly recognized in India. Most of us of the Indian Survey have accordingly adopted terms to recognize the importance of this great erosion interval. For the rocks below, which are all closely folded and generally well foliated, we have adopted, with the meaning sanctioned by J. D. DANA in 1874, the group-name, *Archæan*. The unfossiliferous systems above we group together as *Purana*, a Sanskrit word meaning old and used in Hindu literature for the documents which, though very old, are distinctly younger than, and made up often of, the recomposed products of the ancient *Vedas*, which might well be regarded as Archæan among the literary relics of the past.

The Archæan as thus defined includes an older division of gneisses and schists, many of which like the khondalites of T. L. WALKER, the Mercara and the Behar series, judging from their chemical composition, presumably originated as sediments. These are followed by the Dharwar system, in which the sedimentary characters are generally more completely preserved. Associated with these two divisions of foliated rocks are batholiths of presumably igneous origin. Some of these are older than the Dharwars, and present relationships to the older gneisses and schists similar to those of the Laurentian of Canada. Others invade the Dharwars themselves, and thus correspond with Dr. LAWSON's Algoman. These eruptives occasionally show a marked consanguinity within a definite district, and are then known by separate names, such as the Hosur granite-gneiss, the Sivamalai series of nepheline-syenites, the kodurite series and the charnockites. Although it is well known that these may differ from one another greatly in age, we have not yet attempted to arrange them in tabular form.

In his *Summary of the Geology of India*[2] and in the paper which he has communicated to this Congress Mr. E. VREDENBURG restricts the term Archæan to the rocks "underlying the oldest undoubted sediments." He thus differs from the rest of us in his classification, and I understand that his reasons are briefly as follows: Mr. VREDENBURG lays stress on the occurrence of peculiar banded jaspers as a link between the Cuddapahs and Dharwars, and he points out that the Dharwars are distinctly younger than some of the crystalline gneisses. At the same time, he considers that the sedimentary origin of the so-called para-gneisses and para-schists has not been proved. Mr. VREDENBURG therefore adopts a classification which might fairly be reduced to tabular form as follows:—

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[1] Bull. Dept. Geol. University of California, Vol. III (1902), pp. 56-62.
[2] Published, Calcutta, 1907.

TABLE IV: E. VREDENBURG, 1907.

Palæozoic.

	Vindhyan.
Transition:	Cuddapah.
	Dharwar.

Archæan.

The peculiar banded ferruginous rocks, often referred to as jaspilites and banded jaspers, have long been regarded as a link between the Cuddapahs and the Dharwars, and the fact that such rocks are unknown among the normal fossiliferous systems throughout the world strengthens the idea that there were conditions existing in these very ancient times that have not been exactly repeated since. It is this line of argument that Mr. VREDENBURG relies on mainly to show that the Cuddapahs and Dharwars, having peculiar features in common, ought not to be separated by a great group-boundary line.

We might readily give due importance to this argument, which has of course always been kept in mind by geologists in India. The so-called jaspers do not occur in the Upper Cuddapahs, and as there are marked unconformities among the various members of this system, one is justified in assuming a great range of time between the lowermost and the uppermost Cuddapahs, which are some 20,000 feet thick. If, therefore, one admitted the presence of the so-called banded jaspers as a bond between Cuddapahs and Dharwars one ought to go farther and draw a system-boundary line above what are now known as the Lower Cuddapahs. No one who knows the Cuddapahs in their typical area would tolerate this. In spite of the lithological peculiarity of the lower beds and in spite of the internal unconformities the Cuddapahs form a great natural stratigraphical unit. It is important also to notice that pebbles of banded jaspilite and brecciated veinstones occur in the basement conglomerate of the lowermost division (Gulcheru quartzites) of the Cuddapahs.

At the present time everyone is agreed, I believe, in recognizing throughout Peninsular India the great unconformity dividing the closely folded and foliated rocks of the Dharwar type below from the unfoliated and gently folded Cuddapahs with other such formations above. "In some instances," to use Mr. VREDENBURG's words, "the feebly disturbed, broadly spreading, almost horizontal Kadapah (Cuddapah) strata are observed overlying the contracted Dharwar synclines, the Dharwar boundaries abutting at right angles against the general trend of the Kadapah boundary and the unconformity therefore being of the most thorough kind."

As to whether this line should be regarded as a group-boundary, separating the Archæan from all other younger groups, or whether it should be a mere system-boundary line, subdividing the post-Archæan systems, seems to be the important point of difference between Mr. VREDENBURG and the rest of us. In other words, have the Dharwars below this line more affinities with the crystalline gneisses and schists or with the jaspilite-bearing Cuddapahs above?

In the first place, there are various members of the crystalline schists which might well be merely metamorphosed Dharwars. Among these the quartz-iron-ore schists are most significant, corresponding chemically with so-called banded jaspers. These generally contain much magnetite, and because of the magnetic character of the iron-ore they have been generally referred to as quartz-magnetite-schists. Chemical determination of the ratio between ferrous and ferric oxides show, however, that these so-called quartz-magnetite rocks of the crystalline complex often contain more of the sesquioxide (more hematite, that is,) than the so-called quartz-hematite-schists of the typical Dharwars.[1]

There are other lithological correspondences between the Dharwars and the crystalline schists, but these are of a less significant character. Hornblende-schists and epidiorites are common to both classes of rocks. There is a comparative, but not general, poverty in limestones in both formations. Occurrences of quartzites and talc-schists are often indistinguishable in both cases, while the mica-schists, kyanite-schists and the sillimanite-bearing schists of the series, distinguished by T. L. WALKER as the khondalite series, might well represent some of the altered phyllites of the Dharwars.[2]

It is not assumed that these para-schistose members of the crystalline complex are certainly the direct products of the metamorphism of the Dharwars. In most cases they are probably older than typical Dharwars; but they show that there is no lithological contrast of a kind that would justify one regarding the Dharwars as the products of any fundamental change having occurred at this period in the dynamical geology of the Earth. There is nothing so far to justify us in over-ruling the simple inference that, from a stratigraphical point of view, the Dharwars are more closely related to the fundamental crystalline complex than with the unaltered and but slightly disturbed Cuddapahs.

In the second place, there is a general and, so far as I can remember, complete parallelism between the fold planes of the Dharwars and the foliation planes of the associated members of the crystalline complex. The assumed unconformity between the Dharwars and the basement complex is not based on an observed physical discordance; in some cases, so far as I can find, these unconformities were taken for granted at a time when it was thought that all rocks of obviously sedimentary origin must necessarily have been laid down on the worn surface of the basement complex. In other cases conglomerates in the Dharwars have been taken as evidence of unconformities, and while some of these conglomerates are now known to be crush products,

[1] Cf. T. H. HOLLAND, Mem. Geol. Surv. Ind., Vol. XXX (1900), pp. 111-116, 145, 146.
[2] T. L. WALKER, Mem. Geol. Surv. Ind., Vol. XXXIII, Part 3, 1902, p. 8.

they seldom or never occur at the base of a Dharwar section.[1] Nevertheless, there are probably true conglomerates among the Dharwars, and the pebbles include true gneisses which must have been metamorphosed members of a pre-existing crystalline complex. Such evidence indicates that breaks occurred within the Archæan group, breaks of a kind that indicate a time interval between the oldest known crystalline schists and the youngest Dharwars perhaps as great as, if not greater than, that represented by the whole post-Cambrian record.

Whatever may be the domestic relations of the Dharwars and other members of the Archæan group, they were all formed, folded, foliated and exposed to prolonged denudation before the deposition of the Purana group.

As to the age of the Puranas we have no positive evidence. In spite of what seem to be ideal conditions for the preservation of fossils in the shales and limestones, no determinable organic structures have been found; but any day such may occur, and we may find it necessary to split off portions of recognizable Palæozoic age. The oldest determinable horizon with which the Puranas come into contact is the base of the Gondwana system of Permo-Carboniferous age. One might well expect, therefore, that some day we shall have to give up slices, at any rate of the upper Puranas.

Reference to Table V will show that there is a very close correspondence between the classification accepted by the Geological Survey of India and that drawn up by Dr. A. C. LAWSON for the Lake Superior region. While this correspondence may be true as regards the broad features of these two

TABLE V.

A. C. LAWSON (1913), LAKE SUPERIOR REGION.	T. H. HOLLAND (1906), PENINSULAR INDIA.
Upper Cambrian (Potsdam).	Palæozoic.
Unconformity.	*Unconformity.*
Algonkian: Keweenawan (Nipigon).	Purana: Vindhyan.
Algonkian: *Unconformity.*	Purana: *Unconformity.*
Algonkian: Animikie.	Purana: Gwalior.
Eparchæan Interval.	*Eparchæan Interval.*
ARCHÆAN: Algoman (granite-gneiss, batholithic in Huronian).	ARCHÆAN: Post-Dharwar eruptives.
Irruptive contact.	*Irruptive contact.*
Huronian: Upper.	Dharwar.
Huronian: *Unconformity.*	
Huronian: Lower.	
Unconformity.	*Unconformity.*
Laurentian (granite-gneiss, batholithic in Ontarian).	"Bundelkhand" type of deformed eruptives.
Irruptive contact.	*Irruptive contact.*
Ontarian: Keewatin.	"Bengal" type of schists.
Ontarian: Coutchiching.	Oldest gneisses.

[1] A long list of such sections is given in R. B. FOOTE'S *Geology of the Bellary District*, Mem. Geol. Surv. Ind., Vol. XXV, 1895.

areas, both of which have remained undisturbed since early Palæozoic times, it is not to be expected that such [illegible] of formations will be extended in detail by further research in these areas. It should be understood, also, that in drawing up these parallel tables there is no suggestion that the unconformities and the formations actually correspond in age each with each. By its very nature an unconformity in one area must correspond with some record of deposition in another. It is possible that in the Archæan group there may be unconformities as great as that which we have referred to as the Eparchæan interval. The records below this interval, however, have been so mutilated as to make it now impossible to trace the unconformities over wide areas; thus, the so-called Eparchæan interval is given special prominence, not because it is the greatest of the unconformities, but because it is the one horizon that can be recognized throughout peninsular India. Even this line becomes blurred and unrecognizable in the extra-peninsular areas, which have been subjected to great earth movements, especially in Upper Carboniferous and Cainozoic times. It is almost certain that some, or even most, of the formations grouped together as Archæan in India correspond in age to those known as Archæan in North America; and, because the word Archæan conveys a definite impression to foreign geologists, we have decided to adopt it for the foliated basement complex of the Indian peninsula instead of using such a local name as, for example, *Vedic*, which naturally suggests itself because of the corresponding relationship between the Vedic and Purana literature. We should thus have in India four great natural groups.

1. *Vedic*, which practically corresponds to the Archæan, and thus becomes known;

2. *Purana*, which roughly corresponds to the term Algonkian as originally defined and still used by LAWSON and some other geologists, in spite of the abuse to which it has been subjected at different times;

3. *Dravidian*, for the fossiliferous record stretching from Lower Cambrian to the physical revolution which occurred in Upper Carboniferous times, and

4. *Aryan*, for the record from the Upper Carboniferous base of the Gondwana system to modern times, this record being but locally disturbed.

In dealing with fossiliferous rocks of marine origin it is possible in India to relegate fragments of the Dravidian and Aryan groups to the European Palæozoic, Mesozoic and Cainozoic eras. Except, therefore, as a means of expressing the broad facts of Indian geological history, the terms Aryan and Dravidian are rarely necessary. We are thus left with Vedic and Purana, the former of which might without risk of inaccuracy be translated Archæan. Dr. L. L. FERMOR[1] has suggested that the term Purana might be adopted by extra-Indian geologists to replace Algonkian and Huronian, both of which have been used in so many different senses as now to convey no precise or uniform meaning. Dr. FERMOR's proposal might be useful so long as it is definitely understood that the Puranas of India correspond only broadly in

[1] Records, Geol. Surv. Ind., Vol. XLI, 1912, p. 294.

age with the post-Archæan and generally unfossiliferous pre-Cambrian sediments in other areas.[1]

Although we have arranged the Archæan formations into divisions which are roughly parallel to those recognized by A. C. LAWSON for the Lake Superior region, it is important to remember that an age succession for such rocks can be established only locally, and even locally there are often doubts, due to the fact that it is now impossible, in a highly disturbed and foliated unfossiliferous series of sediments, to distinguish stratigraphically upper from lower; still, it is probable that the classification based on lithological characters corresponds approximately throughout peninsular India with the assumed order of age.

As to the deformed eruptives which are found associated with the schists and gneisses, we see no present hope of ever being able to pass beyond a local classification. Some of our gneissose granites are certainly older than some Dharwars, others are certainly younger. Names like Laurentian and Algoman are deliberately avoided, as most of these bathylithic masses are so placed as to make it impossible to show their age relations to the schists and gneisses. To these, accordingly, we give special names, distinguishing the eruptive complexes which show an unmistakable consanguinity and belong to recognizable petrographical provinces. We thus have—

(1) The charnockite series[2] of pyroxenic rocks, which, though ranging in composition from acid granites to pure pyroxenites, are unmistakably parts of one great series of eruptives.

(2) The Sivamalai series[3] of nepheline-syenites and corundum-syenites.

(3) The gneissose granites of Bellary, North Arcot and Salem, which can be grouped together with reasonable safety over different parts of south peninsular India and probably correspond to the granites of Bundelkhand.[4]

(4) The kodurite series[5] of Dr. FERMOR, which also vary from acid to ultra-basic in composition, being characterized by the presence of manganese-bearing garnets and apatite.

It would be impossible to divide these petrographical provinces into post-Dharwar and pre-Dharwar, and it is safer to allow them to be distinguished as independent units in the great Archæan complex. A similar system of classification appears to me to be suitable to North American conditions, where the term Laurentian has been even more misused than Algonkian and Huronian, while it can only be rarely possible to use the term Algoman. Some of the granite-gneisses of Canada can perhaps be shown locally to be

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[1] The terms Vedic, Purana, Dravidian and Aryan conveniently represent four great eras in Indian geological history. Vedic is unnecessary, as there is no confusion of meaning about the term Archaean; but one cannot form a mental picture of Indian formations without the other three group-names. There is no foreign term to replace Purana, while the European terms, Palæozoic, Mesozoic and Cainozoic would split up such natural units as the Gondwana system and otherwise introduce unnatural division lines.

[2] T. H. HOLLAND, Mem. Geol. Surv. Ind., Vol. XXVIII, 1900, pp. 120, 242.

[3] T. H. HOLLAND, Mem. Geol. Surv. Ind., Vol. XXX, Part 3, 1901.

[4] R. B. FOOTE, Mem. Geol. Surv. Ind., Vol. XXV, 1895, p. 29.

[5] L. L. FERMOR, Rec. Geol. Surv. Ind., Vol. XXXV, 1907, p. 22; Mem. Geol. Surv. Ind., Vol. XXXVII, 1909, p. 243.

post-Huronian, just as some of those of India can be recognized as post-Dharwar, but there must be enormous masses among the so-called Laurentian which may be either pre-Huronian or post-Huronian, and probably both. The recognition of a petrographical province implies a geographical limit as well as a time factor; for a petrographical province indicates a well defined series of geological operations within a limited time and in a limited area, and such a definite geological effort might be conveniently recognized by a distinct name.

SOME PROPOSALS CONCERNING THE NOMENCLATURE OF THE PRE-CAMBRIAN, ETC.

BY

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DEFINITION OF PRE-CAMBRIAN.

To avoid the ambiguity attendant upon the use of the word Pre-Cambrian, either as a designation for all rock formations older than the Cambrian or as a term covering only the youngest Pre-Cambrian sediments, I propose that the Congress adopt the following definition:

Pre-Cambrian comprises all formations older than the basal beds of the Olenellus horizon and may not be restricted to any minor subdivision of this complex.

LIMITATION OF THE PRE-CAMBRIAN.

As many instances are known where the horizon containing the Olenellus fauna is underlain conformably by other sedimentary beds, it is uncertain whether these ought to be included in the Cambrian or not. Some authors have preferred to call such sediments Eocambrian. In any case it is necessary so to define the limit between the Cambrian and the Pre-Cambrian that *no considerable thicknesses underlying the Olenellus beds, nor any rocks separated from them by an unconformity, may be included in the Cambrian (or Eocambrian).*

LOCAL SUBDIVISIONS OF THE PRE-CAMBRIAN.

The Pre-Cambrian of every individual region may be subdivided on a structural basis, using the great unconformities as main dividing planes. The study of contact lines, especially those of the most widely distributed granites, will aid in determining the relative ages of rockmasses. Their correlation will be made more certain by detailed mapping from point to point. Where areas of Pre-Cambrian rocks are cut by political boundaries, their correlation ought to be pursued irrespectively of these. I desire, therefore, to propose the following resolution:

The International Geological Congress expresses the hope that the governments of those countries which possess contiguous areas of Pre-Cambrian rocks will promote the comparative study of such areas by forming international committees that will include representatives of the Geological Surveys of all the *countries concerned, for the purpose of correlating the Pre-Cambrian formations in the different countries.*

HOW SHALL THE GRANITES AND OTHER PLUTONIC ROCKS BE CLASSIFIED?

If the Pre-Cambrian rocks are subdivided in the manner here proposed, the difficulty arises that they contain not only sediments and intercalated eruptives (either effusive, or intrusive between the sedimentary layers, but supercrustal in either case), but also plutonic rocks, *i.e.*, such as were subcrustal or infracrustal when they solidified. When plutonic rocks are found penetrating a lower series B, and are overlain unconformably by a much younger series C, they may be simply designated as *post-B——ian and pre-C——ian.* But as they are more intimately connected with B than with C, they may properly be placed in the same subdivision with B.

The method which has been used in Canada to group together granitic rocks of different ages in the same Laurentian subdivision is, I believe, at variance with the rules of stratigraphical nomenclature which have been followed elsewhere. It is difficult to see any advantage except convenience in such a "sack-designation."[1] It seems obvious that the Laurentian rocks, according as their relations to other rocks and especially to the sedimentary formations becomes better known, will be distributed in various subdivisions, D, F, etc., as post-D——ian, pre-F—— ian, etc.

CORRELATION OF PRE-CAMBRIAN SERIES IN MORE DISTANT AREAS.

In the absence of fossils or other criteria of a similar value it is, for the moment, impossible to correlate with any certainty the Pre-Cambrian successions in regions remote from one another. It may be possible in the future to show that the climates of certain epochs have conferred the same characteristics upon the Pre-Cambrian sediments in different regions, that dynamical disturbances, and volcanic activities in different regions may have been synchronous, and that sedimentary series can be correlated on such bases, but none of these methods has yet been sufficiently elaborated to justify their use in making such wide correlations.

DUAL CLASSIFICATION OF THE PRE-CAMBRIAN.

In the absence of a world-wide chronological classification of the Pre-Cambrian it is not possible to divide this complex into major subdivisions analogous to those of the fossiliferous rocks.

The commonest classification of the Pre-Cambrian recognizes two groups, one containing the sedimentary rocks, the stratigraphical and petrological characters of which have not been greatly obscured by metamorphism or anatexis, and the other such terranes where granitic and gneissic rocks predominate and where the schists of sedimentary origin are so com-

[1] Laurentian as now used means practically that the granites to which the term is applied have not been determined as to age.

plexly intermingled with granitic veins that the contacts with their former basements are frequently unrecognizable.

In America these two great divisions are called *Algonkian* and *Archæan*. It was thought at first that the Archæan might possibly be equivalent to Azoic in its strict theoretical meaning, but it is now admitted by Van Hise and others that it includes highly metamorphosed sediments. Coleman thinks even that the proportion of sedimentary material in the Keewatin is no less than in the younger supercrustal rocks. The same names have been used in Fenno-Scandia and other regions. In Fenno-Scandia, Törnebohm wished to follow the first, strictly theoretical definition of Archæan, according to which it could include no sedimentary rocks. This would have caused the original term Archæan used in Fenno-Scandia to be superseded by Algonkian. However, the term Algonkian has been applied in that region chiefly to the younger, ungranitized Pre-Cambrian sediments. Thus all the typical sediments of the Kalevian, the Bothnian and an unknown quantity of pre-Bothnian formations are left in the Archæan. As the Kalevian fills in a great measure the gap between the Jatulian and the Archæan proper, and exhibits both Algonkian and Archæan characters, the suitability of a dual classification is less apparent than in North America, and I have not, during later years, used the term Algonkian at all, nor will I use it in the future. No doubt the continued study of the older Pre-Cambrian sedimentary formations in America, especially in Canada, will also reveal other older series that fill up the gap in the succession which is so conspicuous in some parts of the Lake Superior region.

As, however, the use of this dual division based on the structure of the Lake Superior region has been so fruitful, and as this division has also been made elsewhere, it seems proper that it should receive the consideration of the Congress. It should be emphasized, nevertheless, that the Archæan and Algonkian designate definite *types* of the Pre-Cambrian rather than groups having definite time values. Rocks of Algonkian type in one part of the world may be equivalent to the Archæan instead of the Algonkian types in another part. I propose, therefore, the following resolution:

Where it has been possible to separate on structural grounds one or several younger Pre-Cambrian sedimentary series from an older basement complex containing schists which are more highly metamorphic and intimately intermingled with granites, the former may be provisionally designated Algonkian, the latter Archæan, both terms being used without any implication of an equivalence with Archæan and Algonkian in other parts of the world.

POSSIBILITY OF THE USE OF GROUP NAMES WITH THEORETICAL MEANINGS.

As long as it is impossible to correlate the Pre-Cambrian series in different parts of the world with approximate certainty, the introduction of terms of group rank and world-wide significance for divisions of this complex is more a theoretical than a practical question. Obviously, the name Algonkian, which is analogous in form to the names applied to systems, cannot always continue to be applied to a division of group rank. The Algonkian and Archæan are, no doubt, at least of the same magnitude as the younger groups, and may possibly even comprise several groups. Various names with theoretical meanings have been proposed, such as *Eparchæan*, *Proterozoic*, *Archeozoic*, *Eozoic*, *Agnotozoic*, etc. CHAMBERLIN and SALISBURY regard Archeozoic as an older group than the Proterozoic, while VAN HISE and LEITH, in their important work, "The Pre-Cambrian Geology of North America," the vade-mecum of every Pre-Cambrian geologist, recognize only one pre-Palæozoic group, the Proterozoic. If we add to the Palæozoic, which already means something old an older Proterozoic, and an even more ancient Archeozoic, the form of this terminology, with almost as many comparatives as ultra-hyper-super-dreadnought, seems to violate the principles of good word-building. Why should the Pre-Cambrian be added as appendices to the classification of the younger groups, when they form a realm of no less chronological importance?

Moreover, the "zoic" character is proved in few cases, which makes a general use of most of these words difficult. This reason induced IRVING to propose the word *Agnotozoic*, which has lately been adopted also by HAUG. But, as I have pointed out before, this word implies a *contradictio in adjecto*, the organisms being either wanting, in which case the group is not *zoic*, or existing, in which case the term *agnotus* is not justified. I have tried to eliminate these difficulties by proposing the term *Progonozoic*, the group of the *ancestral* organisms; this can also be used in the modified form *Progonic*. However, I feel most inclined to propose the introduction of the latter term, not as a designation of the youngest Pre-Cambrian, but as an equivalent for Pre-Cambrian, that would mean a declaration of independence on the part of Pre-Cambrian geology against the geology of the younger groups. This seems justified by the fact that such different methods are employed in the investigation of these respective fields of inquiry. The Progonic could in such case be further subdivided, as I have proposed before, into Neo-Progonic, Meso-Progonic and Archeo-Progonic.

But these proposals are new and have not yet undergone the ordeal of criticism, hence it would be unwise to propose now the adoption of any such term. For my part I think it would be better to leave to the future the adoption of any theoretical names for the different Pre-Cambrian groups, or for the whole of the Pre-Cambrian. But if the Congress should prefer to take any action on this point, I hope that it will consider the terms which I have proposed.

SUBDIVISION ON INTERNATIONAL MAPS.

It seems desirable that more varied colours should be used for the designation of Pre-Cambrian rocks on international maps than have been used heretofore. This could be done, by using different shades of the same colour, without encroaching upon the colour-scheme for the younger sedimentary rocks. At least three divisions would be necessary for Pre-Cambrian sediments, one for the formations which are mainly non-metamorphic (including the Keweenawan, Torridonian, Jotnian, etc.,) one for metamorphic sediments of Huronian or Jatulian type, and one for more highly metamorphic sediments of Archæan type (including the Keewatin, Kalevian, Bothnian, etc.). Three different types of granites should be distinguished, a non-metamorphic type, a slightly metamorphic Archæan type, and gneissoid granites or typical gneisses. At least two designations are required for the basic rocks, one to include the non-metamorphic diabases, basalts, etc., the other for the corresponding uralitized metamorphic rocks ("metabasites"). Of course these groups should be genetic, thus including more or less metamorphic phases as well as the normal phases. A common designation for migmatitic rocks, with which could be joined the granulites (leptynites), is also desirable. Further, as it is impossible to subdivide all Pre-Cambrian areas in such detail, there should be a different colour for unclassified Pre-Cambrian.

THE SUDBURY SERIES AND ITS BEARING ON PRE-CAMBRIAN CLASSIFICATION.

BY

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INTRODUCTION.

The Huronian as defined by Sir William Logan in 1863 was intended to include all of the Pre-Cambrian sediments and eruptives below the Animikie and above the Grenville series and the Laurentian granites and gneisses. In 1885 Lawson separated the Keewatin, mostly of volcanic origin, from the Huronian in western Ontario, and two years later the Coutchiching, a series of sedimentary mica-schists and gneisses. Gradually the distinction between Keewatin and Huronian was extended to other parts of northern Ontario and Quebec, the iron formation of silica interbanded with iron ore serving as a characteristic indication of the top of the Keewatin, while a wide-spread boulder conglomerate was considered to be the base of the Huronian. These two divisions seemed for a time to be all that were necessary and were accepted as fixing the relationships of the Pre-Cambrian in Ontario.

A very serious difficulty arose before long in the application of these subdivisions, for it was found that in some places the basal conglomerate of the Lower Huronian rested unconformably on the Laurentian granite and gneiss and included fragments of them as pebbles or boulders; while other conglomerates, also supposed to be basal Huronian, had been caught in the building of the Laurentian mountains and hence were far older than the Laurentian.

In the earlier and less critical work these contradictions were overlooked, but ultimately an inevitable controversy arose as to the true relation of the Huronian to the Laurentian. President Van Hise and others pointed to the basal Huronian conglomerate resting unconformably on the Laurentian three miles east of Thessalon; while Dr. Barlow and the present writer pointed with equal assurance to the Doré conglomerate near Michipicoten and other examples which were undoubtedly older than the Laurentian, since they had been caught in synclines between the Laurentian batholiths.

Logan in his account of the Huronian in 1863 describes both the Huronian north of Lake Huron and the Doré conglomerate as typical. He evidently considered them of the same age, and he included also conglomerates and quartzites of the Timiskaming region,[1] now described as the Cobalt series.

[1] *Geology of Canada*, 1863, pp. 50-59.

The present writer has for some years felt this difficulty to be very serious, and has attempted to reconcile the two relationships by supposing two eras of ancient mountain-building one before the Huronian and the other after it, parts of the original Huronian having been left undisturbed in the later revolution; or else by supposing that the Laurentian mountain-building continued for a much longer time in some localities than in others.[1]

These explanations were not really satisfactory, and during the past three summers, while engaged in field work in the Sudbury region, a new explanation has forced itself upon me. The conflicting relations of the Laurentian to the supposedly Huronian sediments can be accounted for best by supposing that *there are two series of different ages.* This has actually been proved to be the case in the Sudbury region, where a great sedimentary series underlies the Huronian but is younger than the Keewatin or Grenville series.

Before this was finally proved at Sudbury, Morley Wilson had set apart a Pontiac series in the province of Quebec and the Ontario Bureau of Mines had defined a Timiskaming series below the Cobalt conglomerate generally considered to be Lower Huronian.

The evidence for a great group of sedimentary rocks equivalent in extent and importance to the Huronian and lying between Huronian and Keewatin in age is now so complete that a new classification of the Pre-Cambrian formations of Canada becomes necessary. In this paper a brief account of the Sudbury series and its relations to the rocks above and below will be given, followed by an outline of the distribution of sedimentary formations probably of the same age in other parts of the Canadian shield; and suggestions for a new classification will be presented.

SEDIMENTARY ROCKS OF THE SUDBURY REGION.

The rocks of the Sudbury region were first described in 1856 by Murray, who mapped Wanapitei river and other waterways which traverse the district. He called attention to the steeply tilted quartzite and the basal Huronian conglomerate, but the true relationships were too obscure to be worked out in his rough traverses of rivers and lakes.[2] He naturally made them all Huronian. The Sudbury region was mapped and described in more detail by Dr. Bell and his assistants in 1900, but little headway was made in working out the relative ages of the sedimentary rocks, since most attention was given to the eruptives connected with the nickel ores.[3] Much the same can be said of the excellent work of Dr. Barlow in 1904, in which the eruptives were taken up very carefully, while the sediments received only brief mention.[4] The present writer in a report on the Sudbury nickel field, published in 1905, described the sedimentary rocks in the vicinity of

[1] Pres. Address, Geol. Section, B.A.A.Sc., 1910; and *Methods of Classification of the Archæan of Ontario,* Compte Rendu, Congrès Geol. Int., XIe Session.
[2] Rep. of Progress G. S. C., 1853-6, pp. 145-190.
[3] Ann. Rep. G. S. C., Vol. V, 1890-1, Part F.
[4] Ibid., Vol. XIV, 1904, Part H., pp. 61-67.

the nickel ranges with some detail and mentioned that they were older than the Laurentian and had been upturned and penetrated by Laurentian granite.[1] It was shown also that the boulder conglomerate resembling tillite north of Ramsay lake contained fragments of graywacke and quartzite, so that it was much younger than the other sediments. As the whole region had always been described as Huronian, the graywacke and quartzite were considered Lower Huronian and the conglomerate was therefore placed in the Middle Huronian.

More recent work proves that this was an error. Dr. COLLINS and his assistants have followed the Cobalt conglomerate, always looked upon as of Lower Huronian age, almost without a break to the Ramsay Lake conglomerate; and the present writer has found conglomerate of the same kind resting unconformably on quartzite and other sedimentary rocks from point to point until the typical Huronian is reached 100 miles west of Sudbury. The conglomerate to the west of Sudbury is not as continuous as toward the northeast in the direction of Cobalt, but it is known to occur in thirteen places to the west, sometimes in bands half a mile or more in length. It is probable that many apparent gaps in the continuity will be filled in later since only the vicinity of the Sault Ste. Marie branch of the Canadian Pacific railway was carefully studied. The basal Huronian conglomerate usually has a matrix of arkose or quartzite, and is readily distinguished from the upper conglomerate of the typical Huronian region which often has a slaty matrix.

The unconformity is great wherever the contact of the flat-lying conglomerate upon the steeply tilted quartzites beneath is exposed. The lower rocks had been tilted, more or less metamorphosed and deeply eroded before the Huronian ice-sheet covered them with boulder clay.

RELATION OF THE SUDBURY SERIES TO THE LAURENTIAN.

It has been shown that the sediments here called the Sudbury series are much older than the Lower Huronian basal conglomerate. They are also older than the Laurentian granites and gneisses, as may be seen at various points where the two come together. Going south from Romford, the first station east of Sudbury, along the Toronto branch of the Canadian Pacific railway, one crosses quartzites steeply tilted toward the southeast for two or three miles before reaching the Laurentian contact, which is very distinctly eruptive. The coarse granite or granitoid gneiss penetrates the quartzite, separating bed from bed and providing a good example of *lit par lit* injection; and dikes of ordinary granite and of pegmatite cut the quartzite or quartz-schist in various directions. Similar relationships are found at various points north of Lake Huron also. The quartzites, graywackes and slates of the Sudbury region are then much older than the Laurentian, and must have been deposited and consolidated before the batholithic mountains began to rise.

[1] Rep. Bur. Mines, Ont., Vol. XIV, Part III, pp. 86-93 and 127-129.

WHAT GRANITES AND GNEISSES ARE LAURENTIAN?

Thus far it has been assumed that the granites and gneisses which enclose the Sudbury series or come up through them eruptively are Laurentian, but the question may be raised as to whether these rocks are truly of that age. There are granite boulders enclosed in some of the conglomerates associated with the Sudbury series, which imply older granitoid rocks, and it is probable that there were granites earlier than the Coutchiching also. How is one to discriminate between these different granites?

The granitoid gneisses which have cut or upheaved the Sudbury series are continuous with those underlying the typical Huronian, the rocks actually named Laurentian by LOGAN and MURRAY, as may be seen on the original Huronian map, and gneisses near Wanapitei are named Laurentian by MURRAY. The same is true of the granitoid gneiss of the Doré region, which LOGAN speaks of as Laurentian, and which has upturned and penetrated the Doré conglomerate. There is little doubt that the great batholiths of granite and gneiss of the Rainy Lake region shown by LAWSON to have upheaved not only the Keewatin but also long bands of schist conglomerate apparently of the same age as the Sudbury series, are continuous with the batholithic granitoid gneisses farther east which were named Laurentian by LOGAN; and no reason has ever been given why they should not be named Laurentian except that they are supposed to be later than the Huronian. Now that the conglomerates, quartzites, etc., which were caught in the building of the batholithic mountains are shown to belong to a series older than the Huronian, that objection falls.

Probably the greatest period of batholithic uprise was that of the Laurentian as here defined, and from my own experience in studying the relations in northern Ontario, I am certain that by far the greater part of the surface always coloured as Laurentian on our maps is of this age. No one has pointed out any important area of granite or granitoid gneiss that is undoubtedly *older* than the batholiths here assumed to be the true Laurentian; though there are many instances of later granites, less often of later gneisses.

If granitoid rocks later in age than the Sudbury series and the schist conglomerates and other rocks that have here been grouped with the Sudbury series are excluded from the Laurentian, there will be little left that can be called Laurentian, so far as our present knowledge goes. In any case, when a name has been applied too indiscriminately, so as to cover rocks of more than one age, the name should be retained for the larger part and not for a minor portion of the mixture.

There have been granites formed in all ages of the world and there are, no doubt, magmas now cooling and solidifying as granites at great depths below mountain ranges; so that granite or granitoid gneiss cannot be looked on as characteristic of any one period; and yet the tremendous formation of batholithic mountain ranges after the laying down of the Sudbury and other series of similar age is so far beyond anything of the kind known at any other period in Canada that it deserves a distinctive name, and should retain the name Laurentian actually applied to certain areas of it by LOGAN himself.

RELATIONS TO THE KEEWATIN AND GRENVILLE.

As the Keewatin and Grenville series also are older than the Huronian and Laurentian it might be suggested that the Sudbury series is of the same age as one or both of them. The Sudbury series differs so greatly from the Keewatin as to make it highly improbable that they were formed at the same time. The Keewatin is, in most regions, a characteristically volcanic formation with only subordinate amounts of sedimentary material, mostly that peculiar type of deposit called iron formation, consisting of interbanded jasper, chert or granular silica with hematite or magnetite. Quartzite is seldom found in the Keewatin. On the other hand, the Sudbury series consists essentially of clastic materials, mostly quartzite, and is not known to contain banded silica and iron ore.

As the Sudbury series has not been found in contact with undoubted Keewatin rocks the final evidence for a difference in age must be sought far elsewhere. Farther to the west and north the Doré conglomerate, the conglomerate east of Lake Nipigon, and other similar conglomerates are almost certainly of the same age as the Sudbury series, since they too consist of clastic materials which have been caught in the Laurentian upheaval. As they contain many pebbles of jasper, schist, etc., from the adjoining Keewatin, they are clearly of much later age. The iron range sediments of the upper part of the Keewatin, supposed to have been originally siliceous siderite, were transformed into jasper and greatly eroded before these western conglomerates were formed, and the lapse of time between them must have been great.

Anyone who has compared the green-schists and banded iron ores of the typical Keewatin with the well stratified, cross-bedded quartzites and arkoses of the Sudbury series will have no doubt of the entire distinctness of the two groups of rock, and will feel convinced that the Sudbury sediments could not have been formed at the same time as the Keewatin schists and iron-range rocks of Moose Mountain 17 miles to the north.

Rocks of the Grenville series, possibly of the same age as the Keewatin, come much nearer to the Sudbury series. From the last quartzite south of Romford to the first kyanite-hornblende-schist of the Grenville is little over a mile, and from this point Grenville rocks, greatly cut up by Laurentian eruptives, extend for at least eight miles to the south. Both have been involved in the Laurentian upheaval, but the two groups of rocks are extremely unlike. The Sudbury rocks show all their original structures as sedimentaries and generally have undergone only a comparatively slight metamorphism of the contact type, causing the formation of staurolite and chlorite, or more rarely, mica; while the rocks of the Grenville series have been so profoundly metamorphosed that until recently they were supposed to belong to the ordinary eruptive type of Laurentian.

The most widely spread Grenville rock is coarse hornblende- or biotite-schist or gneiss containing numerous prisms of kyanite and sometimes garnets. Coarsely crystalline limestone with various silicates occurs at one point, and glassy quartzite is found at the quartz mine a few miles south along the railway, which furnishes flux for the nickel smelters. Each type of rock in the Grenville is highly metamorphosed and only slightly metamorphosed in the Sudbury series.

It is possible that the supposed Grenville rocks are merely a portion of the Sudbury series sunk to greater depths in the invading Laurentian magma and so more profoundly acted upon, as Prof. T. L. WALKER once suggested. In that case the Grenville series should be lifted a stage and placed between the Keewatin and the Huronian. The Grenville rocks look so much older than the Sudbury series, however, as to suggest that they had already undergone metamorphism before the latter were formed.

It might be supposed, finally, that the Sudbury series is of the same age as the Coutchiching mica-schists and gneisses which LAWSON has separated from the Keewatin of Rainy lake as an underlying sedimentary group. The Coutchiching schists differ in every way from the Sudbury rocks; they are usually far more completely metamorphosed, and are much older than the western schist conglomerate of Shoal lake, which contains pebbles of them though it is itself probably pre-Laurentian. For these reasons it is highly improbable that the Sudbury series is the equivalent of the Coutchiching.

That the Sudbury series is older than both the Huronian and the Laurentian as they have been mapped and defined north of Lake Huron has been shown conclusively; and the foregoing descriptions of its relations with the Keewatin, Grenville and Coutchiching make it almost certainly younger than those groups. If the western schist conglomerates containing jasper pebbles are of the same age as the Sudbury series, which is very probable, both are manifestly younger than the Keewatin.

From the evidence given in previous pages it will be seen that a distinct series of sedimentary rocks exists in northern Ontario, separated by a great unconformity from the Huronian above and having in many places a basal conglomerate resting unconformably on the Keewatin below.

SIMILAR FORMATIONS TO THE NORTH AND EAST.

Thus far the relationships of the proposed new series have been shown from observations of my own near Sudbury and in several other regions farther north and west, occurring from point to point for 400 or 500 miles. The conclusions reached are strongly confirmed by work done to the northeast by Dr. MILLER and his assistants for the Bureau of Mines of Ontario and by Dr. MORLEY E. WILSON for the Geological Survey of Canada.

About 100 miles northeast of Sudbury is the well known Cobalt region, with its important basal conglomerate in which rich silver ores occur. This was originally classed by the Bureau of Mines as Lower Huronian but it was observed that the conglomerate enclosed boulders of a more ancient conglomerate. Some of these specimens of older conglomerate contain jasper pebbles, so that it must have been formed after the Keewatin. This ancient conglomerate was found near Lake Timiskaming, to the east of Cobalt, and was called the Timiskaming series; and the Cobalt rocks were renamed the Cobalt series, since it was thought that their relations to the original Huronian were rendered uncertain by the discovery of the Timiskaming conglomerate, which was evidently much older.

The Timiskaming series has since been extended to the Porcupine gold region more than 100 miles to the northwest, where it occurs widely and includes quartzite and slate much like those of Sudbury, as well as schist conglomerate.[1] The Timiskaming series is cut by granites and gneisses having the appearance of Laurentian.

Further to the east, in the province of Quebec, the Pontiac series is described by MORLEY WILSON as older than the Huronian and penetrated by the Laurentian. It includes conglomerate and arkose, generally sheared and passing into mica-schist. Its relationship is not entirely certain as far as the Keewatin is concerned, but it probably corresponds to the Sudbury series in age.

Thus formations consisting almost wholly of sediments older than the Huronian and Laurentian, entirely different from the Keewatin, and much younger than the iron ranges of that age have been traced for more than 600 miles across the Archæan of Ontario and Quebec. In extent and thickness they are more important than the Huronian and not far behind the Keewatin. They are equal in systematic importance to either of these two great divisions of the Canadian Archæan and should be given equal rank in the classification. This does away with the formidable difficulty hitherto met in accounting for what seemed contradictory relations of the Huronian to the Laurentian and enables us to arrange a logical system for the tangled groups of rocks making up the Canadian Archæan.

It should perhaps be explained that the word Huronian is here used as equivalent to the "typical" or "original" Huronian as mapped by LOGAN and MURRAY north of Lake Huron. It is not used as including the Doré conglomerate, which LOGAN describes as Huronian. LOGAN never carefully studied the Doré region, since in his description he omitted more than half the width of the conglomerate;[2] and he did not attempt to map it. As this conglomerate is separated from the rocks of the typical region by one of the greatest revolutions known in geology, including the elevation and afterwards the destruction of the great Laurentian mountain ranges, it is manifestly unwise to confuse the two under one name. Logan's brief reconnaissance work on Lake Superior must not bind geology for all time to an incorrect classification of the Archæan.

CLASSIFICATION OF THE PRE-CAMBRIAN.

Of the three regions called Huronian in the 1863 report of the Geological

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[1] Rep. Bur. Mines Ontario, Vol. XXI., Part 1, pp. 219-221.
[2] Idem. pp. 162-165.

Survey of Canada, only one was mapped by LOGAN and MURRAY, that on the north shore of Lake Huron. Their map includes also the adjoining bays of Lake Superior but does not quite touch Point Mamainse to the northwest of Batchewana bay, where characteristic eruptive and sedimentary rocks of the Keweenawan occur. Toward the east the basal conglomerate of the typical Huronian extends over the Sudbury series, as shown in former pages. In the nickel basin of Sudbury an important series of sediments resembles in many respects the Animikie of Thunder bay and is probably of the same age, though Dr. COLLINS thinks this is unproven and would prefer a local name, Whitewater series. Not far to the north of the Sudbury series there is an area of the Keewatin at Moose Mountain; and a little way to the south there are rocks of the Grenville series. Granites and gneisses mapped by LOGAN and later workers as Laurentian and penetrating the Keewatin, Grenville and Sudbury series, but older than the Huronian and Keweenawan rocks, occur at various points.

It will be seen that the region north of Lake Huron, if extended from Point Mamainse to Wanapitei, a distance of about 200 miles, includes areas of every division of the Pre-Cambrian recognized in Canada, with the exception of the Coutchiching and the Hastings series. It not only affords the most complete set of Pre-Cambrian formations known, but includes the most authentic examples of the earliest divisions recognized, the Huronian and Laurentian. The region may properly be looked upon as furnishing the standard for the classification of the Pre-Cambrian of Canada. It is centrally placed and supplies a connecting link between the Pre-Cambrian north and west of Lake Superior and the Porcupine, Cobalt and Quebec areas to the northeast, as well as the Grenville and Hastings regions to the southeast.

The following subdivisions have been distinguished in the region:

Keweenawan (Mamainse, Sudbury nickel eruptive, etc.).
Animikie (Interior of nickel basin, COLLINS' Whitewater series).
Upper Huronian.
Lower Huronian.
Laurentian (In eruptive contact with earlier series).
Sudbury series.
Keewatin and Grenville series.

If we separate the Laurentian as eruptive through the earlier but not the later divisions, we have the following arrangement:

Post-Laurentian:	Keweenawan.
	Discordance.
	Animikie.
	Discordance.
	Upper Huronian.
	Small discordance
	Lower Huronian.
	Great discordance.
Pre-Laurentian:	Sudbury series.
	Great discordance.
	Keewatin—probably equal to the Grenville series.

Whether the Keewatin and Grenville series are equivalent in age is uncertain, since they have not been found together. MILLER and KNIGHT put the Grenville immediately above the Keewatin in eastern Ontario without stating that there is a break between them.[1]

It will be of interest to compare this column of formations with those worked out in other parts of the Canadian shield. Fortunately advance copies of papers presented to the Congress by LAWSON for the region west of Lake Superior and by COLLINS for that east of Lake Superior are available, and recent publications by MILLER of the Bureau of Mines of Ontario[2] and by MORLEY WILSON for the general region are also of service.[3]

In the table given below Column No. I is taken from LAWSON's *A Standard Scale for the Pre-Cambrian Rocks of North America* (Advance edition); No. II represents the results of the work of WILLMOTT and the writer in the Michipicoten iron region, the names being adjusted to the later usage; No. III embodies the classification given above in this paper; No. IV is compiled from reports of the Bureau of Mines of Ontario; No. V is taken from MORLEY WILSON's summary report to the Geological Survey for 1911 (p. 275); and No. VI. is from the legend of a map of Hastings, Addington and Frontenac by MILLER, KNIGHT and ROGERS, published in 1913.

The reasons for the arrangement shown in No. III have been given above. The central parts, including the Huronian and Laurentian, are

[1] Guide book No. 6, Congrès Geol. Int., XIIe Session (1913), p. 56.
[2] Rep. Bur. Mines Ontario, Vol. XIX, Part 2, 1913, p. 48.
[3] Jour. Geol., Vol. XXI, p. 305, etc.

CLASSIFICATIONS OF CANADIAN PRE-CAMBRIAN.

I. Lawson. Rainy lake and Seine river, west of Lake Superior.	II. Coleman and Willmott, Michipicoten, northeast of Lake Superior.	III. Logan and Murray and Coleman, Lake Huron and Sudbury.	IV. Miller, Knight and Burrows, Cobalt and Porcupine.	V. Morley Wilson, Northern Quebec.	VI. Miller and Knight Southeastern Ontario.
Keweenawan. *Discordance.*	Keweenawan. *Discordance.*	Keweenawan. *Discordance.*			
Animikie. *Eparchæan Interval.*		Animikie. *Discordance.*			
		Upper Huronian. *Small discordance.*	Lorrain quartzite, etc. *Small discordance.*		
		Lower Huronian. *Great discordance.*	Cobalt series. *Great discordance.*	Cobalt series. *Great discordance.*	
Algoman (granite-gneiss.) *Irruptive contact.*	Laurentian (granite-gneiss). *Irruptive contact.*	Laurentian (granite-gneiss). *Irruptive contact.*	Lorrain granite. *Irruptive contact.*	Laurentian (granite-gneiss). *Irruptive contact.*	Moira granite. *Irruptive contact.*
Upper Huronian. *Discordance.*					
Lower Huronian. *Discordance.*	Doré series. *Discordance.*	Sudbury series. *Discordance.*	Timiskaming series. *Discordance.*	Pontiac series? *Discordance.*	Hastings series. *Discordance.*
Laurentian (granite-gneiss). *Irruptive contact.*		Granite-gneiss. *Irruptive contact.*	Laurentian (granite-gneiss). *Irruptive contact.*		Laurentian (gneissoid granite). *Irruptive contact.*
Keewatin.	Keewatin.	Keewatin-Grenville.	Keewatin.	Abitibi group.	Grenville.
Coutchiching					Keewatin.

authentic, having been mapped and named by LOGAN and MURRAY themselves. The parts above and below have been added by myself after more than ten summers of field work in the region. The correlation of No. II and No. IV with No. III is largely the result of personal examination of the regions, confirmed on the Cobalt side by the work of COLLINS, who has traced the Cobalt conglomerate to Sudbury. As we get farther away from the central region the correlation grows less certain; but from personal study I feel reasonably sure that LAWSON's Upper Huronian, the Seine series, is the equivalent of the Doré and Sudbury series. His Lower Huronian, the Steeprock series, is more problematic. It is not found in immediate relation to the Seine series and it is in general far less metamorphosed than that series, which LAWSON puts above it. My own impression is that it may prove to be younger than the Seine series, perhaps equivalent in age to the typical Lower Huronian. These rocks are, however, 400 miles from the Michipicoten region and still farther from the typical Huronian region, so that one should be cautious in correlating them. The Quebec rocks of No. V are just across the Ottawa from the Cobalt region so that their correlation is very probable; while that of No. VI, at a considerable distance to the southeast, is more doubtful.

It will be noticed that all the columns show granite or granite-gneiss with an irruptive contact above a great sedimentary series; and that four of them show an older granite-gneiss in irruptive contact with the oldest rocks of all, the Keewatin-Coutchiching or the Keewatin-Grenville series. While they agree in these respects, they differ in the names applied to the two ages of granite-gneiss, LAWSON and MILLER using the name Laurentian for the older of the two and introducing Algoman and Lorrain, respectively, for the younger of the two. As the younger granite-gneiss was undoubtedly named Laurentian by LOGAN himself in the typical Huronian region and at Doré river, it seems natural that the same usage should apply in other regions. From my personal experience in northern Ontario I feel sure that much the greater part of the granitoid gneiss mapped as Laurentian is of the later age, *i.e.* post-Sudbury or Timiskaming. The name Laurentian should be retained for the greater area, which is the later in age, and any new name introduced should apply to the smaller area of older granite-gneiss.

In the classification given above no attempt has been made to combine the divisions into larger groups, since the most essential need is to determine the number of divisions and to correlate them in the different regions. Two interesting plans for larger groupings are given by LAWSON and COLLINS in advance copies of papers read before the Congress, both differing fundamentally from that of the International Committee on the Pre-Cambrian of Lake Superior, which has been in common use by geologists on both sides of the boundary for several years. None of the three arrangements seems to me satisfactory in all respects and it seems better for the present to leave the classification as given above.

In regard to COLLINS' classification (Column III in his paper) the divisions are essentially in accord with those given in Column III on a former page of this paper; though the names employed are in part different, since he was dealing largely with regions to the northeast of Sudbury. His Whitewater series is the same as the Animikie in my column. It is probable, though not a certainty, that the Whitewater rocks are really equivalent to the western Animikie. COLLINS' extension of the term Huronian to include the Animikie and the Keweenawan seem to me of doubtful utility. I should prefer to restrict the term Huronian to the actual formations that were so named in the typical region in the beginning. These are quite definitely known as a whole, though LOGAN and MURRAY hesitatingly placed some rocks with them which we now know are older and which should be excluded. This well-defined group of rocks, the first Pre-Cambrian rocks to be studied and mapped with some care in the great Canadian shield, gives us a fixed starting point for a classification that should not be neglected.

If the eruptive granites and gneisses are left out, the classification just given has the same number of subdivisions as that formerly proposed by the geologists of Finland for the Pre-Cambrian of the Scandinavian shield;[1] they may be placed in parallel columns as follows:

Keweenawan.	Jotnian.
Animikie.	Jatulian.
Huronian { Upper. Lower.	Kalevian { Upper. Lower.
Sudbury.	Bothnian.
Keewatin.	Ladogian.
Laurentian.	Katarchaean.

SEDERHOLM, however, in advance copies of a paper presented before this Congress on *Different Types of Pre-Cambrian Unconformities*, states that the Ladogian, or second division, was erroneously placed in that position, being only a more highly metamorphosed phase of the Kalevian,[2] so that the equivalent of the Keewatin seems to be wanting. But the regions are so far apart that it would be unwise to place too much stress on the parallelism.

[1] Bull. Com. Geologique de Finland, No. 13, p. 155; and No. 23, p. 93.
[2] Idem, p. 4.

A CLASSIFICATION OF THE PRE-CAMBRIAN FORMATIONS IN THE REGION EAST OF LAKE SUPERIOR.[1]

BY

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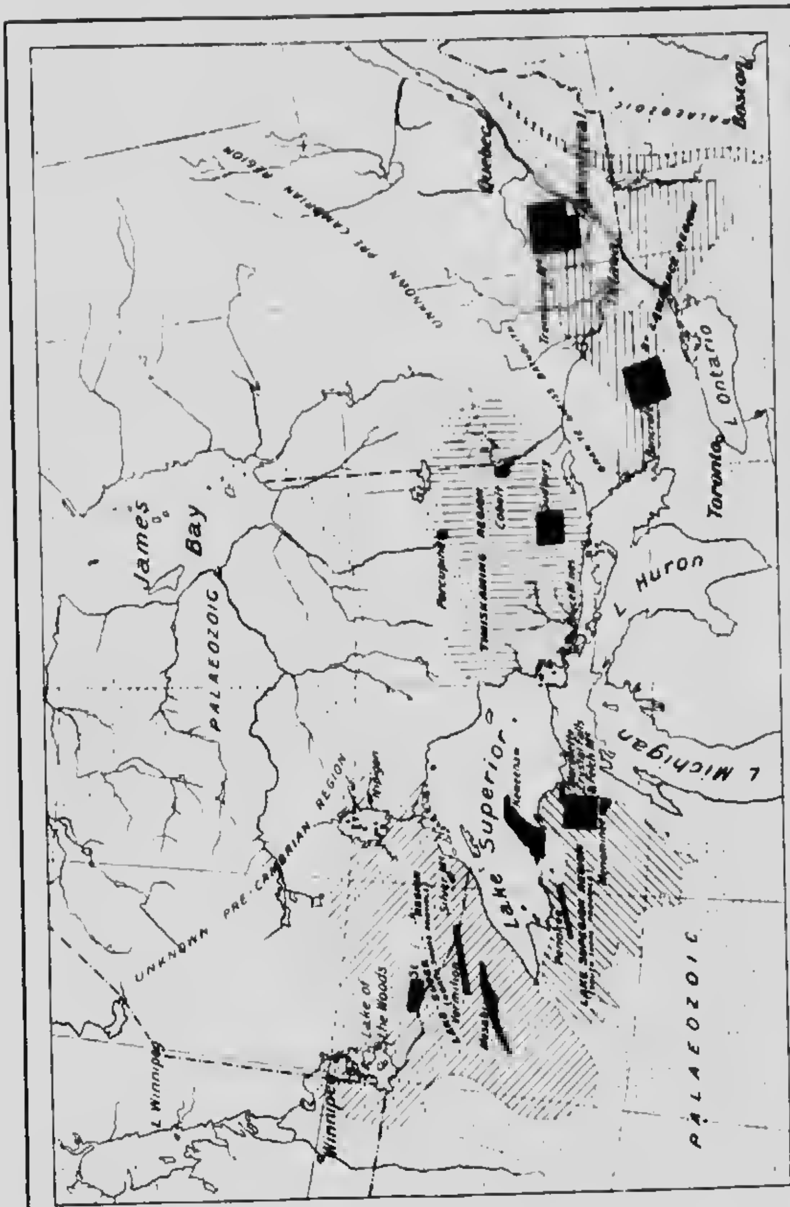
The Pre-Cambrian shield of North America, which occupies 2,000,000 square miles in Canada and the northern United States, is little known geologically except along its southern margin. The great iron, copper, nickel, and other ore deposits that occur in this margin have caused a concentration there of nearly all the detailed investigations that have been made, consequently the geological nomenclature and classification peculiar to the Pre-Cambrian shield has developed almost exclusively in this portion of it near the Great Lakes. Further, this marginal portion is separable into three regions either so isolated from one another or so unlike geologically that they have played distinct parts in the development of the geology of the Pre-Cambrian shield. In fact our knowledge of the Pre-Cambrian shield has been obtained almost entirely in these three regions. They are indicated on the accompanying map and, for present convenience, are called the St. Lawrence, Timiskaming and Lake Superior regions, the last named being sub-divisible into North Shore and South Shore provinces. Areas in each region where detailed work has been done are shown in black. Thus the map presents the territory in which the present nomenclature of the Pre-Cambrian has evolved and the localities that have been critical in this evolution.

It has never been difficult to correlate satisfactorily the sequences found in the various carefully studied *districts* within any one region. These districts are never far apart or can be linked together by study of the intervals between them, and the geological successions in each present many similarities that facilitate correlation. For several reasons most of the difficulties of correlation have arisen in trying to correlate the rocks of one *region* with those of another. The geographical interval to be crossed is large; the geological conditions in the different regions, for instance the Timiskaming and St. Lawrence regions are very unlike; and finally, uniform classifications have been adopted in the past when geological knowledge was very unequally advanced in the three regions. Thus the uniform classification formulated for the Pre-Cambrian shield in 1904 by the International Committee proved

[1] Published with the permission of the Director of the Geological Survey of Canada.



...gram showing regions (in shaded lines) and districts (black) in which the geological nomenclature of the Pre-Cambrian shield has developed.

to be so highly specialized and exacting that its subsequent use in the least known region—the Timiskaming—has been attended with serious chance of error, although the same classification serves well for the better known Lake Superior region.

This paper is restricted as much as possible to formulating a classification of the Pre-Cambrian in Timiskaming region alone, but this restriction is so dependent upon the discreteness of the Timiskaming region from the St. Lawrence or Lake Superior regions that it has been necessary to emphasize the separate existence of all three so far as the problem of Pre-Cambrian correlation is concerned. The St. Lawrence region has never had much in common with the Timiskaming region and may be allowed to drop out of question. But the discreteness of the Timiskaming and Lake Superior regions has not been regarded in the past, and rock classifications have passed back and forth between them to such an extent that the evolution of the nomenclature in use in the Timiskaming region cannot be understood without brief reference in the succeeding paragraphs to the Lake Superior region.

Timiskaming region is separated from the South Shore province of the Lake Superior region by an interval of Palæozoic sediments 130 miles wide. The country between it and the North Shore province is underlain by Pre-Cambrian rocks, but these are so imperfectly known and consist so largely of granite-gneisses that as yet they impede rather than facilitate correlation. This gap is 175 miles across. In this manner are the two regions geologically isolated.

The first Pre-Cambrian classification for North America was applied in Timiskaming region by LOGAN between 1848 and 1855. According to it[1] all the Pre-Cambrian formations were placed in two systems, Laurentian and Huronian. In the former were put the granite-gneisses and such sedimentary formations as were known to be involved in the gneissic complex—at that time, only the Grenville para-gneisses and crystalline limestones of the St. Lawrence region. The Huronian was made to comprise all Pre-Cambrian sediments and associated intrusives that unconformably overlay the Laurentian. LOGAN expressed the same view even more clearly in a later publication[2] in which he says:

"The group on Lake Huron, we have computed to be about 10,000 feet thick; and from its volume, its distinct lithological character, its clearly marked date posterior to the gneiss, and its economic importance as a copper-bearing formation, it appears to me to require a distinct appellation, and a separate colour on the map. Indeed, the investigation of Canadian Geology could not be conveniently carried on without it. We have, in consequence, given to the series the title of Huronian.

"A distinctive name being given to this portion of the Azoic rocks, renders it necessary to apply one to the remaining portion. The only local one that would be appropriate in Canada is that derived from the Laurentide

[1] *Esquisse Géologique du Canada.*

[2] Proc. Am. Assoc. Adv. Science, 1857, Pt. 2, pp. 44-47.

range of mountains, which are composed of it, from Lake Huron to Labrador. We have therefore designated it as the Laurentian series."

It was almost inevitable, owing to the scanty existing knowledge of the country and to a prevailing conception that gneisses were of sedimentary origin, that mistakes should have been made in locating the line between Laurentian and Huronian. LOGAN himself placed in the Huronian certain green schists on the north shore of Lake Huron (Thessalon group) which are intruded by the gneiss, but which he thought lay unconformably on it. MURRAY made the same mistake regarding the sediments near Sudbury. Nevertheless, LOGAN's reports of that time make it quite clear that he recognized elsewhere an important unconformity above the gneiss and sought to make this the boundary between Laurentian and Huronian. And he evidently maintained this opinion, for in his report of 1863, he still separated his Azoic (Pre-Cambrian) into these two divisions. He placed in the Palæozoic the Animikie and Keweenawan formations which we now regard as Pre-Cambrian, but it is perfectly clear that his Huronian was understood to reach to the base of the Palæozoic.

From LOGAN's time until ten years ago the Timiskaming region made slow progress in Pre-Cambrian subdivision. Some of this progress, moreover, was not in the direction that is being taken to-day. For instance, the green schists which LOGAN erroneously put in the Huronian were discovered to be unconformably beneath it; but, instead of excluding them from the Huronian they were called Lower Huronian, thus following LOGAN's evidently erroneous application of the term Huronian instead of following its precise definition. During this same time rapid progress was being made in the Lake Superior region, both in Canada and south of Lake Superior, where enormously valuable iron and copper ore deposits were furnishing an incentive to close geological research. LOGAN's terms were imported from Timiskaming region, but were soon found inadequate for the refinements of such detailed work. They were not rejected, however, but were limited in meaning, subdivided and supplemented with new terms, until a complex nomenclature eventually resulted.

Consequently when, in 1904, the International Committee on Pre-Cambrian Nomenclature re-introduced into Timiskaming region this highly specialized development of LOGAN's classification, in an attempt to bring about a uniform Pre-Cambrian classification for the United States and Canada, difficulties arose. The arrangement was faithfully observed at first by the geologists working in Timiskaming region. For a few years following 1904 the new terms, Keewatin, Laurentian, etc., figured in the literature, positively at first, then interrogatively, and of late years diminishingly as it became realized that the use of these terms required a greater knowledge of geological relations than was at hand. The Lake Superior classification, for such the uniform classification of the International Committee was essentially, was too refined for the needs of the less explored Timiskaming region and did not well suit the geological conditions local in it. Hence, less exacting local names began and continue—to replace those of the uniform classification as this fault became evident.

The opinion now exists among my colleagues in the Geological Survey who are interested in Pre-Cambrian work, that instead of attempting to apply the highly developed nomenclature of Lake Superior region to the Timiskaming region, we should evolve, independently and along similar lines, a nomenclature suitable to the growing needs of Timiskaming region and not in advance of geological facts. A uniform nomenclature can be delayed until there is some equality in our knowledge of the various regions to be correlated. The classification offered below is a result of this policy. It is believed to express the essential facts that are known at present about the geological history of Timiskaming region, and it is hoped that, as new data are acquired, it may be extended, with little or no correction, to give expression to these data.

I.		II.	III.	
Pleistocene.		Pleistocene.	Pleistocene.	
			Unconformity.	
		Silurian (Niagara).	Silurian (Niagara).	
			Unconformity.	
Keweenawan	Latest granite dykes. Olivine-diabase dykes. Granite. Sudbury nickel-bearing eruptive.	Nipissing diabase.	Nipissing diabase, Sudbury norite, etc. — Keweenawan	
			Intrusive contact.	
Animikie	Chelmsford sandstone. Onwatin slate. Onaping tuff. Trout Lake conglomerate.		Whitewater series.	Huronian
Huronian	Ramsay Lake conglomerate.	Cobalt series.	Lorrain series. *Local unconformity.* Cobalt series.	
		Unconformity and erosion.	*Great unconformity.*	
Laurentian granitoid gneiss.		Lorrain granite.	Batholithic granite intrusives.	
		Intrusive contact.	*Intrusive contact*	
Huronian	Acid and basic intrusives. Copper Cliff arkose. McKim greywacke	Timiskaming series.	Sudbury series, Timiskaming series, Fabre series, etc.	Pre-Huronian
		Unconformity and erosion.	*Unconformity.*	
Granite	Pebbles in Copper Cliff arkose.		Granite intrusives	
Lower Huronian (Keewatin).		Keewatin: Greenstone, porphyrite, etc.	Keewatin group.	

Column I of this table is a statement of the Pre-Cambrian sequence found by A. P. COLEMAN in Sudbury district.[1] The oldest rocks in the area examined by Professor COLEMAN are the greywacke, arkose and associated eruptives that constitute the Sudbury series. These are folded closely and intruded by batholiths of granite-gneiss. Both sediments and gneiss are unconformably overlain by a younger, much less metamorphosed conglomerate (Ramsay Lake conglomerate). There is a third, still younger series (Trout Lake conglomerate, Onaping tuff, Onwatin slate and Chelmsford sandstone), regarded as Animikie, but which is intruded and so completely isolated from the older formations by the great laccolithic body of norite with which the ore deposits of the district are associated that its relation to these formations cannot be certainly determined. The norite, together with the dykes and other intrusive bodies of diabase and granite, which intrude all the above formations, are regarded as Keweenawan in age.

A. E. BARLOW[2] believes that, outside the area in which COLEMAN worked, the Sudbury series is antedated by a schist complex of Lower Huronian (Keewatin) age. There are also granite pebbles in the Copper Cliff arkose that imply the existence of a granite formation older than that which invades the Sudbury series. These two members have been added in column I to COLEMAN'S table.

Column II represents W. G. MILLER'S latest classification[3] of the Pre-Cambrian in Cobalt district. A schistose complex of volcanics and subordinate sedimentary matter constitutes the oldest group of rocks (Keewatin) in this district. Infolded with the Keewatin is a conglomerate (Timiskaming series). The Keewatin is invaded by a granite batholith (Lorrain granite), dykes from which also cut the Timiskaming conglomerate. Upon a greatly eroded surface of these older, greatly disturbed rocks lies a gently folded, little metamorphosed series of conglomerate, greywacke and quartzite (Cobalt series). The Cobalt series is intruded by sills and dykes of quartz-diabase (Nipissing diabase).

These districts are 70 miles apart, and until recently the sequences found in them could not be certainly correlated. But the gap between them has been under investigation by the Geological Survey since 1908 and was finally closed last autumn. It was then found that the Ramsay Lake conglomerate in Sudbury district is equivalent to the conglomerate formation of the Cobalt series; also that the Nipissing quartz-diabase grades in this interval into a quartz-norite much like that found in Sudbury district. The Nipissing diabase and Sudbury norite may not be exactly contemporaneous, but the gradation from one to the other suggests that they originated by the same act of intrusion and are therefore of nearly the same age. It is possible now, with this information at hand, to correlate the geological columns of Sudbury and Cobalt districts and to obtain therefrom

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[1] Rep. Bureau of Mines, Ontario, Vol. XIV, Pt III, 1905.

[2] Ann. Rep., G.S.C., Vol. XIV, Pt. II.

[3] Engin. and Min. Jour., 1911.

a more complete sequence for the region. This has been done in column III.

Certain modifications of columns I and II have been introduced in column III.

1. As already stated, the Nipissing diabase, Sudbury norite, etc., are regarded as of the same general age though perhaps not exact equivalents. Their areal distribution, general position in the Pre-Cambrian scale and similarity of their lithological characters and associated ore deposits unite them with the Keweenawan formations south of Lake Superior, hence COLEMAN's usage of this name is followed.

2. The evidence for calling the Chelmsford sandstone, etc., Animikie, does not seem to be as good, so, subject to Professor COLEMAN's approval, the local name, Whitewater series, is substituted.

3. Instead of using Cobalt series as it is used in column II, MILLER's original definition[1] is reverted to and the sediments in question separated into a lower series of conglomerate, greywacke and banded greywacke (Cobalt series), and an upper series of arkose, quartzite and conglomerate (Lorrain series). These two series are in apparent conformity in most places, but an unconformity between them exists locally and, in addition, they appear to have originated under quite different conditions, the Cobalt series being terrestrial, perhaps glacial, and the Lorrain series sub-aqueous. These are the reasons for separating them. There is no disagreement with Dr. MILLER about the facts—only about their relative importance. As the Ramsay Lake conglomerate is the conglomerate formation of the Cobalt series, there appears to be no further need for this term, so it is dropped.

4. The name Sudbury series, though it does not appear in the report of 1905, has been recently adopted by Professor COLEMAN for the McKim greywacke, Copper Cliff arkose and associated eruptives.

5. No precise correlation is intended for the rocks beneath the Cobalt series—only a grouping of formations to express the similarity which exists among the Pre-Cambrian successions in Sudbury, Cobalt, Porcupine,[2] Fabre[3] and other districts. In each of these there appears to have been a period of volcanic activity (Keewatin) which gradually died out and was succeeded by sedimentation (Sudbury series, etc.). There is somewhat remote evidence of an erosion interval and granitic, perhaps batholithic, intrusions between these periods of vulcanism and sedimentation. And there is positive evidence of mountain-building, batholithic invasion and erosion after the deposition of the sediments. It has not been proved, however, that these processes were synchronous in the different districts, and this cannot well be done until our knowledge of the Sudbury, Timiskaming and other series is more extensive than it is at present. For these sediments are the formations in the pre-Cobalt complex which lend themselves most effectively to accurate correlation and that will have to be depended on for a solution of the matter.

[1] Rep. Bureau of Mines, Ontario, Vol. XIV, Part II, 1905.

[2] Rept. Bureau of Mines, Ontario, Vol. XX, Part II.

[3] Rept. Bureau of Mines, Quebec, 1911.

The formations in column III can be grouped, so as to express the larger geological relationships of Timiskaming region, into two major divisions.

All the rocks beneath the Cobalt series are either greatly folded volcanics and sediments or great intrusive bodies of granite-gneiss. They are all notably crystalline and show in pronounced manner the effects of both contact and dynamic metamorphism consequent to mountain-building and batholithic invasion. The names crystalline basement, basement complex, etc., that have been applied descriptively to these rocks as a whole, indicate in some degree how conspicuous these common characteristics are. On the contrary the Cobalt series and other rocks that rest unconformably upon this crystalline complex are modern-looking, little metamorphosed sediments and intrusives. They lie in gently folded attitudes. They are nowhere intruded by batholithic granite-gneiss. So on the far side of the unconformity at the base of the Cobalt series batholithic invasion and mountain-building have stamped all the rocks with common metamorphic characters while on the near side there is no evidence of batholithic invasion, little evidence of mountain-building (in Timiskaming region) and the rocks are correspondingly unmetamorphosed.

As might be anticipated, the unconformity separating two groups of rocks so unlike is regional in extent and of profound chronological value. At all known points in the region the Cobalt series rests upon a crystalline rock surface as maturely eroded and peneplain-like as the present surface of the region. The full chronological importance of the break is perhaps most apparent near Sudbury, where Cobalt conglomerate rests upon the upturned edges of the Sudbury series and upon the gneiss that intrudes the Sudbury series. In the interval between the depositions of the Sudbury series and the Cobalt series, the former was affected by orogenic movements, the granite batholiths were intruded and the mountains so formed were reduced to a peneplain. Some conception of the time required for these changes may be gained from a consideration of the Rocky Mountain region, where seemingly analogous processes have been in progress since Jurassic time at least and are still far from complete. There may be unconformities in the crystalline complex equal to that at the base of the Cobalt series, but none equal to it are known in the Pre-Cambrian above.

The unconformity at the base of the Cobalt series is thus a conspicuous successional hiatus that separates the Pre-Cambrian of Timiskaming region into an older division characterized by batholithic invasion and extreme metamorphism, and a younger division showing no such invasion and subordinate metamorphism. There are no names now for these two divisions. The classification of 1904 does not recognize them, for, according to it, the term Huronian would be applied to sedimentary formations in both of these divisions. LOGAN recognized them in 1848 as they are recognized to-day and called them Huronian and Laurentian, though, hampered by a scanty knowledge of the country and by a misleading conception of the nature of gneisses and schists, he did not always locate the plane of separation correctly. But, since LOGAN'S time, Huronian and Laurentian have been given different meanings, consequently these names cannot be used again in the original sense without explanation. There seems to be only two ways in which LOGAN's two terms may be retained: by following either the wording of his definition or the application of this definition. If the latter alternative be taken there is no justification for any present usage of either term, for none of these usages coincides with LOGAN's. But if the wording of his definitions be applied to the data available at the present time, the names Huronian and Laurentian will then apply exactly to the sequences in column III, repectively above and below the unconformity at the base of the Cobalt series.

Fortunately the term Huronian is now used in a sense not greatly different from this. Huronian can therefore be applied to the upper division in column III without creating great confusion. If it is not applied to this division it should, according to the rules of nomenclature, disappear and this, considering its priority and long standing in geological literature, would be regrettable.

The present usage of Laurentian by the International Committee is very different from that of LOGAN, and a return to LOGAN's usage would be attended by more confusion. Moreover, the crystalline complex in Timiskaming region is still so imperfectly known and its chronological significance is so much less definite than that of the Pre-Cambrian above it that a term co-ordinate with Huronian is scarcely suitable for it. Our knowledge of the time significance of this complex is accurately conveyed by the word pre-Huronian, where Huronian refers to all the Pre-Cambrian above it. So, for the present at least, a re-instatement of the original term Laurentian may be left in abeyance, and pre-Huronian substituted for it.

The usage of the terms Huronian and pre-Huronian in column III may now be summarized. Huronian is applied to all Pre-Cambrian rocks in Timiskaming region above the unconformity at the base of the Cobalt series. The lower boundary of this division is definite and unmistakable. The upper limit is not so sure for at present the Keweenawan is regarded as Pre-Cambrian and is therefore included in the Huronian, but in case later investigation should determine it to be Palæozoic, it would be removed from the Huronian. The upper limit of the Huronian is the upper limit of the Pre-Cambrian, whatever that may prove to be. This is a point which will doubtless be settled in some other Pre-Cambrian region, for in Timiskaming region the relations between Cambrian and Pre-Cambrian are poorly exemplified. Pre-Huronian is applied to all the rocks beneath the unconformity at the base of the Cobalt series. It is entirely possible that the pre-Huronian may eventually be subdivided into two or more parts each co-ordinate with the Huronian, hence this term, pre-Huronian, is to be regarded as temporary one.[1]

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[1] Since this paper was prepared essentially the same conclusions have been expressed independently by Messrs. W. G. MILLER and C. W. KNIGHT (Engineering and Mining Journal, June 7, 1913, pp. 1129-1133). The opinions advanced here are accordingly offered with added confidence.

PRE-CAMBRIAN CORRELATION FROM A LAKE SUPERIOR STANDPOINT.

BY

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Papers presented to this Congress and elsewhere recently have contained a bewildering variety of suggestions and contentions for revision of the nomenclature and classification of the Pre-Cambrian of Lake Superior and Ontario. When one considers the nature of Pre-Cambrian correlation, its dependence, not upon fossils, but upon lithology, sequence, conditions of deposition, metamorphism, relations to intrusion,—in short on physical conditions,—and especially when one considers how little is really known about problems of sedimentation, metamorphism and structure, so fundamental to correlation, it is not surprising that there should be various ideas of correlation, and that earlier classifications should be modified or replaced by new ones. The variety of suggestions which have been offered may, at first thought, give the impression that the subject is in the state of hopeless confusion. But analysis of the suggestions indicates that real progress is being made. Their very number and the insistence with which some of them are urged, are indications of the virility of the attack on the problem. It is the purpose of this paper to discuss from the Lake Superior standpoint some of the proposed changes in correlation and names, in the attempt to single out if possible the real advances from the tentative suggestions.

The several papers will be taken up seriatim and then together.

A. C. Lawson: A standard scale for the Pre-Cambrian rocks of North America; International Geological Congress, Toronto, 1913.

Most of the contentions of this paper are not new; they have been urged and considered for many years. This new and emphatic presentation of them by Dr. Lawson seems to call for a restatement of the position of the Lake Superior geologists who have failed to adopt his suggestions. He cites the Lake Superior region as a type Pre-Cambrian region which should serve as a standard for Pre-Cambrian nomenclature and classification, and proceeds to propose such a standard, ignoring, by implication, the fact that a standard has already been established in the field and so well confirmed by the work of so many different geologists and mining explorations that most of it is beyond the hypothetical stage, and must be accepted unless disproved by equally careful and intensive work. The changes are urged on the basis of short examinations of one of the outlying Lake Superior areas, the Rainy Lake district, which has not been mapped in great detail except along the water's edge and is not nearly so well known as the great iron and copper districts of the Lake Superior region, which have been studied so closely for so many years. They are not based on any new evidence developed in the best known parts of the Lake Superior region,—in fact, they do not take account of results of recent work in these areas.

Coutchiching.—Keewatin greenstones and green-schists, originally largely basaltic flows, with minor shreds of interlaminated sediments such as iron formation and slate, have been regarded as the base of the Pre-Cambrian succession of the Lake Superior region. Associated with the Keewatin in the Rainy Lake district is a series of micaceous and hornblendic slates and schists, some of undoubted sedimentary origin and some of which are schistose phases of the Keewatin basalts. To all of these schists Dr. LAWSON gave the name Coutchiching. He regards the Coutchiching as lying beneath the Keewatin, and therefore would introduce the Coutchiching series as the lowest member of the standard Lake Superior succession.

Considering the surficial nature of the Keewatin lavas and their known interlamination with sediments, there is no improbability that sediments may somewhere be found below it, but in spite of the fact that LAWSON'S suggestion was made many years ago, it has not found wide acceptance among students of Lake Superior geology for the following reasons:—

(1) In a schistose complex of rocks standing so nearly on edge, it is difficult to prove, in the absence of basal conglomerates, the sequence of adjacent beds. The fact that Coutchiching rocks in some places dip under Keewatin rocks cannot be accepted as conclusive, because in other places Keewatin rocks can be found to be dipping under Coutchiching rocks. In many parts of the Vermilion district there are great jasper beds interlayered with the Keewatin basalts, but mainly above them. Unconformably above both is a series of Huronian sediments in part like the Coutchiching. In certain localities one could argue for the inferior position of the jaspers or Huronian on the same kind of evidence used by Dr. LAWSON in his Coutchiching problem, yet the real Vermilion sequence has been ascertained only by the most careful and detailed mapping, over wide areas, checked by mining and exploration development. Until this work is done conclusions based on summer reconnaissance trips within a limited area can be only surmises.

(2) A large part of the series which LAWSON originally classed as Coutchiching, in fact one of the largest areas he described as typical Coutchiching, he now admits is later than and unconformably upon the Keewatin. He calls it the Seine series. This part of the Coutchiching he says is unconformably above another part of the original Coutchiching series. From a detailed consideration of his field work we are doubtful whether he has succeeded in proving this unconformity. Fair consideration of his evidence must lead to the conclusion that this so-called unconformity between two parts of the original Coutchiching is largely inferred and perhaps influenced by the desire to prove such a situation.

(3) Other parts of the original Coutchiching have been found to be merely

schistose phases of the Keewatin basalts and not sedimentary. These parts are now eliminated from the Coutchiching. More such parts are likely to be eliminated.

(4) After taking from the Coutchiching the rocks above mentioned, it is doubtful how much, if any, of the series is left to meet LAWSON's definition of Coutchiching.

If it should prove that there is a residuum of Coutchiching sediments actually beneath the Keewatin of Rainy lake, it remains to be proved that they are below the lowest Keewatin, and that they are not interbedded sediments in the Keewatin on a somewhat larger scale perhaps than known sediments in the Keewatin in the Vermilion and other districts. In this connection, the fact should be noted that the thickness of the so-called Coutchiching sediments has not been determined and, in the nature of the case, will not be determined for a long time, because folded and fissile slates give very little evidence of original bedding. It may not be said, therefore, on the basis of present evidence that the series is a thick one. In the event of some of the Coutchiching sediments being proved to be beneath the Keewatin of this particular locality, the most that can be said is that here are sediments conformably beneath at least a part of the Keewatin, with no evidence that they are anywhere near the bottom of the Keewatin, or that they constitute anything more than interlayered sediments.

LAWSON seemed to recognize the fact that the Coutchiching series is closely related to the Keewatin and in fact a part of the series, when he suggested that both the Keewatin and Coutchiching be subordinated to a general term Ontarian. From our standpoint, if it be found that the Coutchiching is really below the part of the Keewatin found in Rainy lake, Keewatin is sufficiently general to include both. If, as we suspect, all the Coutchiching is found to be unconformably above the Keewatin, as LAWSON now admits that a large part of it is, there is still more reason for retaining the term Keewatin for the basement.

Lake Superior geologists are influenced by another consideration, and that is the existence, in the Vermilion district and its eastern extension into Ontario, to the southeast of the Rainy Lake district, of a series of sediments demonstrated to be unconformably above the Keewatin, and similar in many respects to the Coutchiching sediments. The sequence has been proved beyond question, and is accepted by LAWSON in the paper under discussion. In reconnaissance trips through Rainy lake, Lake Superior geologists see a similar series lying in the same apparent relations to the Keewatin and are naturally slow to accept a conclusion that in so short a distance the sequence of two similar series should be reversed. They are rather inclined to take the ground that the more intensive Vermilion study indicates the probable sequence and that the Rainy lake mapping is more in the nature of a tentative approximation of the situation, which may ultimately have to be superseded. There is, of course, danger of too strong a bias being carried over from the Vermilion district, but the situation certainly warrants a conservative attitude in withholding judgment as to the real position of the Coutchiching until detailed work has been done. Certainly, no evidence has thus far been presented which would warrant the introduction of the term Coutchiching into a standard Lake Superior classification, the units of which have all been proved by repeated and careful geological surveys, supplemented by a large amount of underground work.

(5) These facts were all considered by an International Committee composed of representative geologists from the United States and Canada, and this committee refused to accept the conclusion of the inferior position of the Coutchiching. The Canadian members of the committee certainly cannot be accused of any bias against LAWSON's views, having adopted them more or less in Canadian publications, and the reference to this committee's report as a "triumph of diplomacy for the geologists who proposed it" is a weak answer to the statements of fact agreed to by the committee.

Algoman.—LAWSON would introduce the general term Algoman, coördinate with Laurentian, for the batholithic acid intrusions into the Middle and Lower Huronian series of Lake Superior. If this be done, another general term should be introduced to cover the batholithic intrusions into the Animikie, and still others to cover the several periods of basic intrusion. We see no need at the present time for the introduction of so many new names. The experience with the term Laurentian has been so unfortunate, in that it has been many times applied without sufficient evidence of age, that one is slow to offer additional waste-baskets in which to throw intrusives. There is no difficulty at present with the use of local names for these intrusives. In fact it would seem that the logical course for the future, as suggested by SEDERHOLM, may be rather to cut from the standard classification the term Laurentian, the only term applied to intrusive rocks, and to use merely local names for intrusions into the different series. However, the term Laurentian has become so intrenched in the literature and there are so many large areas for which the term Laurentian is a convenient one, that probably this logical course will not be followed for many years to come.

In passing, it may be noted that Dr. LAWSON argues for the restriction of the term Laurentian to the acid intrusions in the pre-Huronian complex, implying that this is a new suggestion. This restriction is the one which for twenty-five years or more has been used by the Lake Superior geologists and which was urged on the International Committee by these geologists. LAWSON's suggestion is, therefore, not for a change, but for the retention of the present standard usage of this term in the Lake Superior region. The International Committee approved this usage, but with the reservation that for present expediency it would be necessary to use the term Laurentian in a broader sense, to include acid intrusives of several ages, for parts of Canada where the term had already been applied in this broader sense and where it was not yet possible to separate the periods of granitic intrusion. From our standpoint the restriction of the term is highly desirable to make it conform to the present Lake Superior usage.

Eparchæan Interval.—The most important of Dr. LAWSON's contentions and the one which has been most urgently put forth in the past, is that the great unconformity beneath the Animikie or Upper Huronian series should be used as the principal basis for classification and regarded as the "Eparchæan interval." The importance of this unconformity is fully recognized by all geologists who have studied it. Dr. LAWSON quotes from VAN HISE and LEITH's account of it in emphasizing its importance. Lake Superior geologists have mapped and studied this unconformity with the greatest care in connection with their detailed mapping of the Mesabi, Gunflint and Animikie districts where this unconformity is the most conspicuous. In fact these geologists have made almost the only detailed studies that have been made of these districts. Yet they have failed to put this unconformity in the centre of the picture, and are now told that their failure to do so has been a stumbling block to Lake Superior geology, and that thereby even their moral characters are under suspicion. Why is it, then, in spite of the recognition of this great unconformity, that it has not been interpreted as the great Eparchæan interval?

On the north side of Lake Superior, Animikie or Upper Huronian rests nearly flat upon a highly tilted, highly metamorphosed and much intruded complex of igneous rocks and sediments. When traced to the south into Cuyuna district, only thirty miles south of the Mesabi, the Animikie series in turn becomes intruded by granite and is as much folded, metamorphosed and intruded as the sediments below. The same is true of the south side of the lake. Great intrusions of northern Wisconsin are found to be post-Animikie, and even highly metamorphosed terranes like the Quinnesec schists are now regarded as probably Animikie. The soft, yielding nature of the great mass of the Animikie has, in fact, favoured more intense metamorphism than in the older series. Furthermore, the principal deformation of the south shore has been post-Animikie, rather than pre-Animikie, the Animikie sediments having been laid down as nearly flatlying Middle and Lower Huronian sediments. Southward from the north shore, therefore, the Eparchæan interval is not the spectacular and easily recognizable structural discordance that is found on the north shore.

When the unconformity is considered for the entire region it becomes apparent that it is no more or less important than another unconformity, that between the Middle and Lower Huronian of the south side of the lake. For that matter, notwithstanding its conspicuous character on the north side of the lake, it is difficult to prove that this unconformity is any more important than that between the Huronian or Keweenawan rocks. All of these unconformities are overshadowed by the great one at the base of the Huronian series. It merely happens that on the north side of the lake, where LAWSON and his associates have principally seen it, it has a spectacular emergence. Dr. LAWSON admits that there are other unconformities in the Pre-Cambrian sediments and presents no evidence to show that these are not fully as important as his so-called Eparchæan interval. When asked why he selected one of the unconformities as the principal basis of classification, and ignored the others, he failed to answer.

In the greater part of the Lake Superior region, particularly in the

Marquette, Menominee, Crystal Falls, Iron River and Gogebic districts, the rocks on the two sides of the unconformity marking this so-called Eparchæan interval stand nearly parallel in attitude, with similar metamorphism, and, as a group, have Huronian aspect. It is yet not at all certain what parts of the Huronian rocks of the south shore of the lake are to be finally correlated with the two divisions of the Huronian north of Lake Huron. Also there are parts of the Lake Superior region where rocks are Huronian in their aspect, but where it has not yet been possible to subdivide them, or to correlate them with any one of the Huronian divisions. To make the pre-Animikie or pre-Upper Huronian plane the principal basis for the division of the Lake Superior Pre-Cambrian would leave sediments of identical Huronian aspect both above and below it and would be an entirely arbitrary and impracticable procedure that would not express the facts which a good classification should express.

As a corollary to his emphasis on the unconformity at the base of the Animikie, Dr. LAWSON would give different group names to the sediments above and below. Those below he would call Huronian, those above Algonkian. In other words, Huronian would be restricted to the present Middle and Lower Huronian, while Algonkian would be restricted to the present Upper Huronian or Animikie and the Keweenawan. Algonkian and Huronian would be coördinate terms rather than Huronian being subordinate to Algonkian. Even if Dr. LAWSON were right about the dominant importance of the unconformity, the retention of these two terms in their new sense would introduce great confusion into the literature. In view of the fact that his insistence upon the dominance of this unconformity is due to lack of comprehension by him of the facts of the district as a whole, and especially of the importance of other unconformities, the introduction of new terms has nothing to support it. They would fail to express the facts now expressed by the present classification. For instance, in many areas of undivided Pre-Cambrian sediments it would be necessary to call them "Algonkian or Huronian." In places where the sediments are divided, we should call part of them Huronian and another part identical lithologically, structurally, and in metamorphism, Algonkian. It would be an arbitrary division between series of like character. There would be exactly the same reason for using either of the other two planes of unconformity between Pre-Cambrian sediments as a basis for division between Algonkian and Huronian.

In the earlier days of Lake Superior mapping, several geologists thought it desirable to restrict the term Huronian to the sedimentary series below the Animikie, but as knowledge of the region widened, it appeared that such classification would be applicable to only a very limited part of the region close to the lake on the north shore, and would not be practicable anywhere away from the lake shore, either north or south, for the reason stated in preceding paragraphs.

Emphasis on the pre-Animikie unconformity as the principal basis of classification of the Pre-Cambrian sediments of Lake Superior region is not a new suggestion. Several Canadian geologists, familiar principally with this unconformity as it appears on the north side of the lake, have made suggestions of a similar sort. The difference in emphasis on this unconformity has been an unfortunate source of controversy between United States and Canadian geologists. It seems to us that this undue emphasis on the pre-Animikie unconformity has been due almost entirely to failure to look beyond the north shore of the lake and consider this unconformity in its manifestations on the south and west sides of the lake. If it were true, as has been argued repeatedly in recent years, that this unconformity everywhere separates highly metamorphosed, intruded and folded sediments and later, flat-lying, little metamorphosed, folded and intruded sediments, then it would be reasonable to use it as a practical basis of field classification, but this is true only in limited parts of the Lake Superior region, and is emphatically not true when considered for the region as a whole.

W. H. COLLINS: A CLASSIFICATION OF THE PRE-CAMBRIAN FORMATIONS IN THE REGION EAST OF LAKE SUPERIOR; INTERNATIONAL GEOLOGICAL CONGRESS, TORONTO, 1913.

This paper is of especial interest as summarizing the recent work of the Canadian Geological Survey in the area east of Lake Superior. Considerable advances have been made in areal connections of formations, particularly between the Sudbury and the Cobalt districts. Mr. COLLINS makes an effective plea for the use of local names in the present stage of mapping in order not to have the situation confused by the application of general terms from without. This is highly desirable, for while there is now substantial agreement as to local successions and names, there are a variety of opinions as to how these should be so correlated with the Huronian and other series of Lake Huron and Lake Superior. Mr. COLLINS' classification is as follows:—

Pleistocene.		
Unconformity.		
Silurian (Niagara).		
Unconformity.		
Nipissing diabase, Sudbury norite, etc.	Keweenawan.	Huronian.
Intrusive contact.		Huronian.
Whitewater series.		Huronian.
Lorrain series.		Huronian.
Local unconformity		Huronian.
Cobalt series.		Huronian.
Great unconformity.		
Batholithic granite intrusives.		Pre-Huronian.
Intrusive contact.		Pre-Huronian.
Sudbury series, Temiskaming series, Fabre series, etc.		Pre-Huronian.
Unconformity.		Pre-Huronian.
Granite intrusives.		Pre-Huronian.
Keewatin group.		Pre-Huronian.

There is in this great region a great unconformity separating little metamorphosed and folded sediments (Cobalt series, etc.) from a much more metamorphosed and folded basement (including Sudbury, Temiskaming and other sediments) intruded by great granite batholiths. This seems to Mr. COLLINS to mark a great dual division of the Pre-Cambrian. The rocks above he would call Huronian, those below pre-Huronian. There is likely to be little dissent from his use of local names, the sequence of rocks, and the emphasis for practical field purposes on the unconformity below the upper group of sediments, which have not been intruded by plutonic granites. His use of the general terms Huronian and pre-Huronian for the two great divisions, however, involves a correlation with the north shore of Lake Huron which is tentative.

MILLER AND KNIGHT: SUDBURY, COBALT AND PORCUPINE GEOLOGY; ENGINEERING AND MINING JOURNAL, JUNE 7TH, 1913.

MILLER and KNIGHT have studied for the Ontario Bureau of Mines the Sudbury, Cobalt and Porcupine, and other areas which have been studied independently by the Canadian Geological Survey. Their conclusions, published at the same time as COLLINS', show a remarkable agreement on essential facts. Their succession follows:—

Dikes of aplite, diabase, etc
Intrusive contact.
Nipissing diabase.
Intrusive contact.
Cobalt series
Erosion contact.
Lorrain granite
Intrusive contact.
Temiscaming series
Erosion contact.
Laurentian granite and gneiss
Intrusive contact.
Grenville series.
Keewatin

The essential difference between this table and that of COLLINS is that it includes the Grenville series, which is regarded as conformably superposed upon the Keewatin, in much the same manner as the Soudan iron formation of the Vermilion district, Minnesota, is superposed upon the Keewatin. They argue that the Grenville, being a much more extensive sedimentary series than the Soudan iron formations in the Vermilion district, should have a place such as that accorded to the Keewatin, Laurentian, Huronian or the Keweenawan. They do not emphasize any particular unconformity of the Pre-Cambrian and suggest general correlation only in the most tentative terms, implying that most of the Cobalt and Temiskaming series may be found represented in the original Huronian district, and therefore may be called Huronian. The assignment of the Grenville to a position below the Huronian is based on its close association with rocks of supposed Keewatin age and upon the existence of limestones beneath the Cobalt and Sudbury groups of sediments. MILLER and KNIGHT's work on the Grenville-Hastings area near Madoc, which is almost the first attempt to determine the structure and sequence of the Grenville, seems to bear out the conclusion that the Grenville series is related to a greenstone basement and is overlain by sediments of the Huronian type. The Grenville series as a whole is separated areally from the typical Huronian rocks and no place has been found where definitely recognizable type exposures of both are in juxtaposition. Until such places are found the assignment of the Grenville to a pre-Huronian period must be regarded as tentative.

A. P. COLEMAN: THE SUDBURY SERIES AND ITS BEARING ON PRE-CAMBRIAN CLASSIFICATION; INTERNATIONAL GEOLOGICAL CONGRESS, TORONTO, 1913.

Rocks which had in earlier work been classed generally as Huronian in the Sudbury district are now divided into a lower series of quartzites and graywackes, tilted, more or less metamorphosed and intruded by granites, lying unconformably below a flat-lying conglomerate (Ramsay Lake) which has been traced by COLLINS into the basal conglomerate of the Cobalt series. Unconformably above both are the little metamorphosed sediments of the Sudbury basin (Whitewater series). COLEMAN calls the lower series the Sudbury series. He restricts the Huronian to the Ramsay Lake conglomerate. The upper series he calls Animikie. The granite and gneisses intrusive into the Sudbury series, but older than the Huronian or Cobalt series, are called Laurentian, on the ground that intrusives of this type constitute the greater part of what has been called Laurentian in the past and that granites and gneisses unconformably below and older than the Sudbury series are in such limited amounts that the restriction of the term Laurentian to them would be a depature from past procedure. The Sudbury series is regarded as later than the Keewatin on the assumption that the relations are the same as in the Michipicoten district, where the Doré conglomerate, or the supposed equivalent of the Sudbury series, rests unconformably upon the Keewatin. The supposed Grenville rocks and the Sudbury series occur within a mile of each other near Romford. Both have been involved in the so-called Laurentian upheaval. It is possible that the supposed Grenville rocks are merely a portion of the Sudbury series sunk to greater depth in the invading Laurentian magma, but they are regarded as probably older than the Sudbury series.

COLEMAN agrees with COLLINS in emphasizing the break above the Sudbury series and in calling the Sudbury series pre-Huronian. He differs from COLLINS in not including in the Huronian the upper series, calling that

Animikie. The discrimination of Animikie from Huronian has also been made by LAWSON.

MORLEY E. WILSON: THE SIGNIFICANCE OF RECENT DEVELOPMENTS IN THE PRE-CAMBRIAN STRATIGRAPHY OF THE LAKE SUPERIOR-LAKE HURON REGION; JOURNAL OF GEOLOGY, VOL. XXI, 1913, PP. 385-98.

WILSON emphasizes the existence of a dual division of the Pre-Cambrian through the area extending from the north shore of Lake Huron northeast through the Sudbury, Cobalt, Porcupine, Larder Lake and Mistassini districts, in all of which gently folded sediments, not affected by granite batholiths, rest upon a highly metamorphosed, folded basement intruded by granite batholiths. In the first division he includes the Cobalt series, the original Huronian sediments and their equivalents. The lower series includes the Keewatin green-schists, closely associated with sedimentary rocks described under various local names,— Pontiac schist, Fabre series, Temiskaming series, Sudbury series, etc., all of which are intruded by Laurentian batholiths. The emphasis on the great plane of unconformity above the series affected by batholithic intrusions and the attempt to make this a basis for correlation and nomenclature is similar to that argued by COLLINS, but WILSON favours an enormous extension of this idea, namely that this great plane of unconformity is the one beneath the Animikie on the north shore of Lake Superior and that it also extends under all of the Huronian formations on the south side of Lake Superior. He bases his argument for the extension of this plane beneath the Huronian of the south side of Lake Superior upon (1) an assumed absence of batholithic intrusions in the Huronian or Animikie on the south side of Lake Superior; (2) on the possibility that in the limited areas of pre-Huronian schists of the south shore of Lake Superior there may be sediments which have thus far been overlooked, corresponding to the Lower and Middle Huronian sediments on the north shore of the lake; (3) on the lithological differences between pre-Animikie sediments on the north and south sides of the lake. In view of the fact that all of the Huronian rocks on the south side of the lake, including the Animikie, are fundamentally metamorphosed and deformed by batholithic intrusions, as shown especially in the Cuyuna, Menominee and Florence districts, and in view of the fact that no trace of sedimentary series associated with the Keewatin beneath the Huronian has been found in detail studies over many Lake Superior areas, WILSON's interesting suggestion must be regarded as only tentative, without substantial basis of evidence. The paper was written without knowledge of the recent discoveries of extensive batholiths into the Huronian rocks, which had not yet been fully discussed in literature, although they appear in accounts of the Cuyuna iron range. So far as the writer can see, there is no new evidence to warrant change in the suggestion made some years ago by VAN HISE and LEITH in Monograph LII. of the U.S.G.S., as follows:—"It thus appears that the assignment of the rocks under discussion (Lower-Middle Huronian north of Lake Superior) to the general place of Lower Huronian and Middle Huronian is unquestioned. But as large portions of these rocks may be land formations, they cannot be exactly correlated with the aqueous deposits of the Middle and Lower Huronian to the south. The deposition of land sediments may well have begun earlier than that of the aqueous deposits or it may have continued later."

GENERAL DISCUSSION.

The main feature that is common to three of the preceding papers is emphasis on the existence of a great plane of unconformity in parts of Ontario and the Lake Superior region, separating an upper series of unmetamorphosed and little folded sediments from a deeply eroded basement of highly folded and metamorphosed sediments intruded by granite batholiths, and the assumption, specifically stated or implied, that this unconformity is the same in age in widely separated districts.

With this essential idea as a basis, general terms are used for correlation on which the various writers show little agreement. COLEMAN restricts the Huronian to the lower of two series above the unconformity in the Sudbury district, using Animikie for the upper. COLLINS and WILSON are inclined to restrict the term Huronian to the series above this unconformity. WILSON argues that this unconformity really goes beneath the Huronian of the south side of Lake Superior. LAWSON, on the other hand, carries it only beneath the Animikie. He would use the term Algonkian for the rocks above this unconformity and the term Huronian for post-Keewatin sediments below this unconformity. MILLER and KNIGHT adhere rather closely to local terms, though they suggest correlation of sediments both above and below this plane with "Huronian" sediments of the original Huronian district.

It is assumed that there is only one plane of unconformity of this sort, which is very wide-spread. COLLINS has traced an actual areal connection of this unconformity between the Cobalt and Sudbury districts, and lithological and structural similarities probably warrant its extension to certain outlying areas in Ontario and Quebec. This is a definite and satisfactory step in advance. That this plane is the same as that beneath the Huronian sediments of the original Huronian district or that beneath the Animikie of the north shore of Lake Superior, or that beneath the entire Huronian series of the south side of Lake Superior, is an assumption not based on areal connection, but projected because of certain crude similarities across wide areal gaps. So far as the Lake Superior region is concerned, there is no warrant for the use of this plane as the main basis of classification. One has only to recall the short distance of 30 miles between the Mesabi and Cuyuna districts, in which this plane of unconformity becomes tilted and folded by reason of batholithic intrusions into the series above this plane, the upper beds being fully as much metamorphosed, in some places more metamorphosed, than the beds below. Also throughout the southern central portion of the Lake Superior region, including the Gogebic, Marquette, Menominee, Crystal Falls and Iron River districts and northern Wisconsin, the simple and conspicuous elements of this unconformity are obscured by folding and later batholithic intrusions. In this part of the region there is another unconformity within the Huronian sediments, of equal magnitude so far as anyone can tell. In this part of the region also, these unconformities are not more significant than the unconformity between the Keweenawan and Huronian. All are overshadowed by the great plane at the base of the Algonkian. These being the facts, anyone urging that the pre-Animikie unconformity of the type observed on the north side of Lake Superior is the Eparchæan interval, which should be used as a main basis of classification for the Lake Superior region, virtually ignores such facts.

If it is impossible to use such an unconformity as the main basis for classification and correlation between near-lying districts within the Lake Superior region, it is clear that any attempt to extend it across greater unknown areas to the original Huronian and Sudbury districts is only a guess affording a very doubtful basis for correlation. The distances are much large than those in Lake Superior district in which remarkable changes in this plane are known. Considering the complete change in the aspect of the "Eparchæan" unconformity within short distances in the Lake Superior region, which has been proved again and again by detailed study, it seems desirable in the present state of knowledge that the use of such a plane for purpose of correlation in Ontario should be tentative. It is entirely conceivable and probable that some of the highly folded and metamorphosed sediments in one area may turn out to be equivalent to the little folded and nearly flat-lying sediments in another, the difference being due to batholithic intrusions. Considering the wide-spread distribution of batholithic intrusions of at least three great periods in the Pre-Cambrian, now definitely recognized, it would indeed be surprising if this situation should not be found in many parts of Ontario, and so far as it is found, the use of an unconformity rendered conspicuous by batholithic intrusions in the lower series is not conclusive as a basis of classification and general correlation.

Emphasis on lithology alone as a basis for correlation is now regarded by all as dangerous. The emphasis in the papers above referred to is not only on lithology but on structural and metamorphic characteristics and relations to intrusions. The basis has been broadened, but it is still not final.

We conclude, then, that in each of the Pre-Cambrian districts above referred to, the general sequence and structure are fairly well agreed to and there is little opportunity for dispute as long as local names are used. A probable exception to this is the assignment of the Coutchiching to a position below the Keewatin of Rainy lake. In the Lake Superior region it has been possible with reasonable certainty, to group the various formations and series into general divisions for the region as a whole. Within the Lake Superior region correlation still presents many problems, but as a whole it has been substantially checked by the work of so many men and organizations, through so many years, that it is past the hypothetical stage. Correlation of certain Ontario districts which are not far separated has also reached a sound basis. When the attempt is made to correlate the Lake Superior formations with those of the several Ontario districts, or those of widely separated districts in Ontario, such correlations in the present state of knowledge must be regarded as largely preliminary and tentative, and certainly not sufficient to warrant sweeping changes in general nomenclature in any district. There seems to be a tendency to place too much confidence in the maintenance of the uniformity of a plane of unconformity and the assumption that planes of this type found in different parts of the same region are necessarily one and the same plane. As a working hypothesis for near-lying areas, it is extremely useful. When this assumption of uniformity of such a plane, found in certain areas of Ontario, is carried over to the Lake Superior region, it runs squarely against a vast body of ascertained facts. It furnishes an insufficient basis or warrant for any drastic revision of the division or correlation of the Lake Superior rocks. This classification has grown by a process of evolution during many years of laborious study of the area. However it may fit elsewhere, it certainly expresses the facts essentially for the Lake Superior region. If it be discarded or seriously modified it will be as a result of studies of the Lake Superior region itself. Inferences drawn from distant areas may be helpful and welcome, but not in themselves decisive.

DISCUSSION SUR LES SUBDIVISIONS, LA CORRÉLATION ET LA TERMINOLOGIE DU PRE-CAMBRIEN.

A. C. LANE (Boston): Collins' paper has covered the decade of the introduction of the terms Huronian and Laurentian as divisions of the Pre-Cambrian. In the decade between 1860 and 1870, first-class geologists like Credner (in his *Habilitationsschrift*),[1] Brooks and Pumpelly followed the usage of the introducers of the terms and divided the Pre-Cambrian (Vorsilurische, or Eozoic) into Laurentian and Huronian. It is a question of literary taste whether this well-fixed usage, taken up by the great text-books *e.g.* that of Dana, should be overturned and whether, if new wine be found, it should not be put into new bottles.

In all probability it will be found, if Newberry and Schuchert's theory that periods of geology are marked by world-wide cycles of sedimentation be true, that the Huronian as originally defined and mapped, covering the Animikie, contains three such cycles. In that case, the Huronian may be divided into Animikean and two other periods. But why change the use of the term Huronian? This will lead to endless confusion. Give each of the three cycles and periods its own name.

Is it proved that, as Lawson implies, the "original Huronian" near Sault Ste. Marie contains no Animikie? My observations there do not convince me of this. It is also to be noted that the Animikie is more disturbed on the south shore of Lake Superior than the upper part of the "original Huronian."

A. C. LAWSON (Berkeley, California), replying to Professor C. K. Leith, said that he had not ignored by implication the existing nomenclature and classification of the

[1] *Die Gliederung der eozoischen (vorsilurischen) Formationsgruppe Nordamerikas*, Halle, 1869.

Pre-Cambrian. On the contrary he had printed it in full and discussed it freely, pointing out its defects. The changes were urged not on the basis of short examinations of the Rainy Lake district, with detailed mapping only along the water's edge, but after a careful re-study of the district and mapping on a field scale of a quarter-mile to the inch, involving numerous traverses, and after a review of the literature of the Lake Superior geology, to which abundant reference was made in his paper, particularly to the latest statement given in Monograph LII of the U. S. Geological Survey. He exhibited a geological map of a portion of Rainy lake on a scale of half a mile to the inch showing the evidence for his interpretation of the Archean geology of that district, and stated that his detailed work in 1911 had substantiated the evidence set forth in his report of 1887. He did not claim that the evidence as to the reality and stratigraphic position of the Coutchiching was new, but that it was true, that it had never been examined by his critics in the significant sections, and that it must be recognized whether it be new or old.

Mr. LAWSON said that the real reason for the denial of the existence of the Coutchiching below the Keewatin was the peculiarly dogmatic doctrine, promulgated by the U. S. Geological Survey, that no sediments occurred in the Archean, that it was wholly igneous. This doctrine has in recent years been abandoned as untenable. Under its influence, however, it was first denied that the Coutchiching rocks were metamorphosed sediments, and subsequently, when their sedimentary character could no longer be doubted, it was asserted that they were above the Keewatin, although the geologists who made this assertion never took the trouble to examine the sections at Bear's Passage and Rice Bay, which were described in the report of 1887 as proving the superposition of the Keewatin upon the Coutchiching. Mr. LEITH, he said, had advanced several formal reasons for the non-acceptance of the stratigraphic position of the Coutchiching, but these were not worth discussing in view of the unchallenged and positive field evidence easily observable at Bear's Passage and Rice Bay. At Bear's Passage the stratification of the Coutchiching is not confounded with the schistosity, the strata are not "standing nearly on edge;" they form a well defined anticline with flat-lying strata in the axis and steepening dips on the flanks, passing beneath the Keewatin on both sides. On the west side they pass beneath the Keewatin at angles of from 20° to 30°. The section is, moreover, easily accessible, and it is psychologically remarkable, to say the least, that the geologists who deny the relations there revealed should not have visited the section during their different visits to Rainy lake. Mr. LEITH's statement that "one of the largest areas described as Coutchiching is now admitted to be later than and unconformable upon the Keewatin" is erroneous, as is shown by the map at his side. A relatively small strip of the rocks mapped as Coutchiching on Seine river was found to belong to a later series, and the Coutchiching remains as mapped in 1887, with but little change.

As to the recognition of the post-Huronian granite batholiths as Algoman, a term coordinate with Laurentian, Mr. LEITH agrees that it is highly desirable to restrict the term Laurentian to the pre-Huronian granites. But without a definite designation for the post-Huronian Archean granites, which are now known to be very extensive, this restriction cannot be made, as current usage up to this time clearly shows. The reference for all granites of Archean age to the Laurentian under the guise of present expediency, when it is positively known that they belong to two widely separated ages, obscures geological history and retards progress. The desirability of restriction of the term Laurentian being conceded, no further argument is necessary.

Mr. LEITH's objections to the recognition of the Eparchean Interval as a dominant fact in the classification of the rocks of the Lake Superior region do not weaken its importance. The fact that there is another profound unconformity at the base of the Huronian, the Epi-Laurentian Interval, is freely recognized in the paper, but emphasis has been laid upon the Eparchean Interval, owing to the fact that VAN HISE, LEITH and others habitually slur it over and minimize its significance by making the term Algonkian and Huronian straddle a great time break. If the Animikie strata, as everybody agrees, were laid down on "a remarkably uniform peneplain—a flat plane levelling alike hard and soft, resistant and non-resistant rocks" in the Mesabi, Animikie and Gogebic districts, it is clear that a large section of geological time unrepresented by sediments is involved, which finds no expression in the geological scale if the interval is to be spanned by a systemic name like Algonkian or Huronian. The rocks properly called Huronian are certainly on the far side of that interval and the Animikie on the near side, and the obscurities of the south shore are no warrant for ignoring a large fact which is as clear as day on the north shore of Lake Superior. Mr. LEITH's contention that the Epi-Laurenti

Interval is of equal importance is agreed to in the paper which he criticizes, but no one has attempted to bridge that interval by a systemic name including rocks on both sides of it, since the Keewatin was segregated from the Huronian. The introduction of the "great confusion into the literature" which Mr. LEITH deplores is not due to the recognition of the significance of the Eparchean Interval and the taxonomic consequences which flow from it; but is due rather to the unwarranted, unnecessary and vicious imposition of the term Algonkian upon the literature in such a way as to displace the term Huronian as a division of the Archean, and at the same time blur hopelessly the geological record. The term Algonkian is well enough as a name for a system of Pre-Cambrian rocks, but the only system to which it can apply is that embracing the Animikie and the Keweenawan, since on the far side of the Eparchean Interval the term Huronian cannot be displaced.

The terms of the standard scale as set forth in his paper Mr. LAWSON claimed are expressions of geological fact. They represent major events in their ascertained sequence. Being the most complete and unequivocal sequence yet formulated, it is proper that it should be erected as a standard for purposes of comparison and correlation. The only debatable question is that of coördination, and his own view of that is expressed in the tabulation of the paper.

Professor LANE: Did not LOGAN then describe these rocks as Cambrian?

Dr. LAWSON replied that LOGAN in the *Geology of Canada*, 1863, did not class the Animikie as Huronian, but as a later series.

C. K. LEITH (Madison, U.S.A.): Dr. LAWSON says he is glad to admit the existence of other unconformities possibly of the Eparchean type. This is what we claim. Why then should the unconformity at the base of the Animikie be made the principal basis of classification and nomenclature. Any arguments advanced for the emphasis on one unconformity will apply equally well to the other.

J. J. SEDERHOLM (Helsingfors): The Eparchean interval seems to correspond to the great break which exists in some parts of Fenno-Scandia between the Jatulian and its basement. There, as here, we place the upper limit of the Archæan at that break, but since the discovery of great thicknesses of Kalevian rocks, often directly underlying the Jatulian, I think we have less need of such a term as that proposed by Dr. LAWSON.

I perfectly understand the reasons which have brought our Canadian colleagues to adopt the present use of the term Laurentian, but I continue to think that it might be better to give it up altogether. Many geologists have thought till lately that there was in the Pre-Cambrian of northern Europe an oldest basement complex consisting mainly of gneisses and granites possibly older than all sediments. I once shared that opinion. But now we are aware that many of those gneissose and granitic rocks are younger than certain sedimentary schists of the same region and we therefore try to map them with different colours according to their ages.

A. P. COLEMAN (Toronto): The original Huronian was very carefully mapped by LOGAN and MURRAY, and was divided into upper and lower subdivisions. The Animikie was not included in it. The error of putting it into the Huronian was due to IRVING's belief that the Animikie represented LOGAN's Huronian.

After careful study of the original Huronian I have not found any granites or gneisses penetrating them. Therefore I cannot agree with Dr. LAWSON in defining the Algoman as granites and gneisses penetrating the Huronian.

A. E. BARLOW (Montreal): I am rather surprised that Dr COLEMAN should maintain that there are no important batholiths later than the Huronian, for in his most recent work, *The Nickel Industry*, he mentions that the nickel eruptive, presumably of Keweenawan age, is cut by dykes of later granite, apophyses from and genetically connected with a batholith which occupies an area of many square miles in the Sudbury district. He further relates that the later olivine-diabase dykes, which the present speaker has always regarded as differentiates of the nickel eruptive, are cut by little dykes of granite. Dr. COLEMAN also states his belief that "this last eruption probably took place somewhere in Paleozoic time." May I then ask Dr. COLEMAN if this is not a fair and proper interpretation of his latest description of the geology of Sudbury district.

Sir T. H. HOLLAND (Manchester), pointed out that some misunderstanding appeared to exist as to LOGAN's views regarding the relation of the Huronian to the rest of the Pre-Cambrian of the Great Lakes region. LOGAN first divided the rocks of the area into five groups, drawing special attention to the great unconformity between the foliated and folded groups 1, 2 and 3 below and the simply folded formations 4 and 5 above. The lowest two groups afterwards became the Laurentian, while the more certainly sedimentary formations above became known as the Copper-bearing series. For the first ten years after the Survey commenced in 1846, LOGAN tried to fit the Canadian rocks into the standard scale of Europe and thus relegated the oldest unaltered local sediments to the Cambrian. But in 1857 he felt compelled to separate his group 3 under a separate name, Huronian, limiting the term to the folded sediments below the great unconformity, that is, below what were afterwards named the Animikie. There is no doubt whatever that LOGAN very clearly distinguished between the Huronian and the "Upper Copper-bearing series" or Animikie. But in summarizing the reports of his assistant, MURRAY, LOGAN made the error of referring to the Huronian at the *mouth* of the Kaministiquia river, instead of at the *falls*, which are some 20 miles from the shore of Thunder bay. This error became repeated in the *Geology of Canada* published in 1863, and numbers of geologists were consequently misled by supposing that the easily accessible rocks of Thunder bay represented LOGAN'S original Huronian when, as a matter of fact, they belonged to the "*Upper* Copper-bearing series." Most of the subsequent confusion and controversy can be traced to this simple clerical error, as was pointed out by Dr. G. M. DAWSON when the British Association met in Toronto in 1897.

The speaker agreed with Dr. SEDERHOLM in objecting to the use of system names for intrusive bathyliths, and he recommended the system introduced by him in India of recognizing by special names well defined petrographical provinces among the Archæan intrusives. The recognition of a petrographical province implied an age as well as an area and they thus had in India the charnockite series, the Sivamalai series, the kodurite series, etc. These might or might not wholly or in part correspond to the Laurentian of Canada; no one could settle such a point, and nothing would be gained by attempting the impossible task of correlating the Archæan intrusives of widely separated areas; analogies could be recognized, but not equivalence of age.

A. E. BARLOW: Before reaching a decision regarding the formation of any committee on Pre-Cambrian classification and nomenclature I would like to make a few remarks. In the first place the geologists invited to join such a committee should be men of wide acquaintance with and interest in the subject. They should preferably have firm convictions, reached after years of critical examination and study in various regions where Pre-Cambrian rocks are typically exposed. My experience with men of so-called judicial mind has been that they have no "mind" at all and are most concerned in trying to reach some compromise decision. Truth will not admit of compromise. The men, therefore, who are to compose such a committee should be chosen for fitness only, and not by reason of their official position. I oppose in the strongest manner any abandonment of the use of the term Laurentian at a time when we understand better than in the past, its true import. The use of names to designate as "series" certain local developments of these old crystalline rocks, urged by Sir THOMAS HOLLAND, seems to me only to add to the complexity of the subject, for we know that the nepheline- and other alkali syenites found in the Laurentian massif, and which are comparable with HOLLAND'S Sivamalai series of India, are a peripheral expression of the more usual or prevalent Laurentian granites and gneisses. I am deeply grateful that Archean geologists of all countries are in such close agreement on questions of interpretation and classification. At the same time I am in hearty sympathy with Dr. LAWSON in his determined stand for world-wide recognition of the importance of batholithic intrusion as representative of time and area in geological history and his emphasis on the great lapse of time represented by the Eparchæan and other intervals.

G. A. J. COLE (Dublin), asked his Canadian colleagues to consider seriously whether in justice to the original views and definitions of Sir WM. LOGAN, the term Laurentian might not be abandoned, except as representing an opinion which profoundly influenced the reading of the Archæan succession all over the world. That reading having, in the progress of research, become greatly modified, the name Laurentian ceased to be desirable, as it could no longer be applied to the ancient stratigraphical horizons for which it was devised. Similarly, the greatly respected term Silurian, owing to various definitions given to it, has been abandoned by several European workers.

Professor COLE also pointed out that Dr. STRAHAN had naturally based his accou of Pre-Cambrian rocks in Ireland on Irish publications of the Geological Survey of t British Isles. These, however, were now some 20 years old and the views expressed them had been departed from in many respects by geologists in Ireland at the present da The gneiss of the northwest, for instance, was now known to be intrusive in the Lou Foyle (Dalradian) series, and it was to be regretted that the only official statement of t fact occurred, so far, in two minor publications of the Department of Agriculture for Ireland. He felt that it was the duty of the Irish Survey, and thus his own duty, to rectify these matters at an early date.

J. HORNE (Midlothian), expressed amazement not only at the divergences of opinion but at the contradictory statements that had been made regarding the facts of North American Pre-Cambrian geology. He was of the opinion that names of formations might come to have broader significances than the conditions existent in the original locality would indicate. Thus the term Lewisian is now so used that the rocks in the locality where this name was originally applied are no longer very typical.

Dr. LAWSON replying to Dr. HORNE, said that his statement that the Huronian was cut by granites was based upon Professor COLEMAN's papers.

A. P. COLEMAN: Dr. BARLOW has quoted Prof. COLEMAN as contradicting Prof. COLEMAN, and quite correctly. In earlier writings I followed the usual belief as to the Huronian. Since then new light has come, placing the Sudbury series, which is cut by the Laurentian, below the Huronian. This will explain to Dr. HORNE the apparent contradiction.

T. C. CHAMBERLIN (Chicago), stated briefly the grounds on which the Pre-Cambrian is divided into Proterozoic and Archeozoic, to which allusion had been made. A portion of the Pre-Cambrian sediments present the products of mature disintegration, while the earlier portions are usually characterized by partial or immature disintegration. The former are best typified by the great beds of quartzite that imply the complete disintegration of large quantities of quartz-bearing rock and the subsequent assortment and reduction of its quartz particles. The slates and schists imply the same process, but in their metamorphosed condition they are less easily and safely distinguished from pyroclastic and other material of different origin. Mature disintegration implies some restraining agency that held the rock in place while the slow weathering process completed its work; otherwise the products of incomplete disintegration would have mingled with quartz and given an arkose or equivalent product. In the later ages the chief restraining agency was the mantle of vegetation, so that this view favours the existence of a vegetal covering of the land as far back as great terranes of quartzite occur. By hypothesis the classification thus comes to have a semi-organic basis; but this is not essential to the classification which is based on the dominant processes attending the sedimentation. The Proterozoic is thus made to include terranes that bear great quartzite formations. The earlier formations not so characterized are grouped into the Archeozoic.

L. L. FERMOR (Calcutta), referring to Dr. HORNE's paper presented at the morning session, pointed out that Dr. HORNE had given a resumé of the various opinions held on the Lewisian gneisses, Moine schists and Torridonian sandstones, but that he had omitted to mention what many were probably wishing to hear, namely, the equivalence of the Dalradian schists to the remainder of the Scottish crystallines. He asked Dr. HORNE if he would kindly express an opinion on this point.

Dr. FERMOR also referred to the interesting discussion on the nomenclature of the North American Pre-Cambrian rocks. He pointed out that the classification of the Pre-Cambrian rocks of India advocated by Sir T. H. HOLLAND had been prepared at a time when the classification of the American Pre-Cambrian was in a state of confusion. Since HOLLAND's scheme had been put forward it had been tested by the Indian Geological Survey and found to be of great use. The majority of officers of that department found that HOLLAND's classification was peculiarly suitable to India. The speaker had never been able to understand why some such similar scheme should not also be applicable to North America. The great stumbling block had been the various statements prevalent as to the relation of the Laurentian to the other members of the Pre-Cambrian complex of North America. Professor LAWSON in his paper had now made these relations perfectly clear by separating the Algoman from the Laurentian batholithic rocks. The speaker thought that Professor LAWSON's paper would be received with great satisfaction by many Indian geologists.

A. STRAHAN (London), the chairman of the meeting, observed that this meeting was the close of a series of notable papers and discussions on the problems relating to the Pre-Cambrian rocks. He was indebted to Professor COLE for calling attention to literature on the Pre-Cambrian rocks later than that which he had consulted. He also remarked that, if this Congress should be notable for nothing else, it would be for the light cast upon this subject by the discussion that had taken place.

Sujet No. 6 : Dans quelle mesure l'époque glaciaire a-t-elle été interrompue par des périodes interglaciaires?

THE INTER-GLACIAL PROBLEM IN THE BRITISH ISLANDS.

BY

G. W. LAMPLUGH, F.R.S.

St Albans, England.

In complying with the request of the Executive Committee of the present Congress by submitting the following contribution to the proposed discussion on inter-Glacial periods, I should first mention that my views on the subject were fully expressed in a presidential address[1] to the Geological Section of the British Association at York in 1906, and have not since been modified in any essential particular. My criticism was then, as now, directed against the interpretation of the British drift deposits as being the product of alternating periods of glaciation and *complete* deglaciation. It has been an essential part of the inter-Glacial hypothesis as applied to Britain that the ice-sheets which covered most of the land and filled the neighbouring shallow sea-basins were melted out entirely during at least one warm inter-Glacial period and reappeared at a later stage.

In the address referred to I dealt categorically with the evidence from various parts of the British Islands known to me from personal investigation, and showed that in such parts I had sought in vain for proof of any complete interruption of glacial conditions during the period represented by the drifts. I have since re-examined the crucial sections of the Yorkshire coast and some other parts of the east of England, and have also been able closely to investigate fresh areas in the Midland counties and in the borders of North Wales where it has been supposed that inter-Glacial conditions were represented; but again without finding any justification for the hypothesis. It is therefore with increased confidence that I reiterate my former conclusions.

In previously dealing with the subject, I introduced references to the literature relating to the glaciated parts of Europe and North America for the purpose of showing that there is no general agreement as to the validity of the inter-Glacial hypothesis in its application to other countries. But, lacking sufficient personal knowledge, I did not then, and shall not now, attempt to evaluate the evidence from areas outside the British Islands; and it is only by implication that the inter-Glacial schemes proposed for other areas come within the range of my objections to the hypothesis. Since, however, the inter-Glacial idea was founded and elaborated principally on the

[1] *On British Drifts and the Interglacial Problem.* Rep British Assoc. for 1906, (1907), pp. 532-558. Full references to the literature of the subject will be found in footnotes to this address, and it is unnecessary for me to repeat them on the present occasion.

British evidence, it is of particular consequence that the value of this evidence should be put to the proof. As our islands lay always along the outer limits of the Northwest-European area of glaciation, it is, of course possible that the whole of our comparatively low-lying drifts may represent only a single stage of a series of successive glaciations elsewhere fully represented. If so, the hypothesis may yet prove to be correct for the drifts in some other areas, though inapplicable to the British deposits on which it was largely based. But, in view of the evidence of the earlier and later conditions to be gleaned from the beds below and above them, it seems to me unlikely that our British Glacial drifts can be thus interpreted.

If we review the history of the inter-Glacial hypothesis in British geology, we find that the idea was first entertained to explain the presence of sands and gravels among the boulder clays. The glacial origin of our boulder clays was established long before it was recognized that the widespread sheets of well-stratified material associated with them might also be the product of land-ice, and that such fluvio-glacial deposits were an essential outcome of the glaciation. It was thought that the sands and gravels must have been deposited in the sea, this opinion being fortified by the discovery that they contained fragmentary marine shells in many places. Shell-bearing gravels were found at elevations of 1,200 and 1,300 feet above present sea level on the flanks of the mountains of eastern Ireland and North Wales, so that it became necessary to postulate a submergence of this amount during some stage of the Pleistocene period. The stratified beds were seen to be often intercalated with the boulder clays, and were therefore supposed to represent a single and definite stage of submergence, although it was pointed out by many observers that they recurred at different horizons in the Glacial series.

A triple classification of the British drifts was thus established, comprising (1) a Lower boulder clay, produced by ice; (2) a Middle-Glacial marine series, deposited during the supposed submergence; and (3) an Upper boulder clay, produced either by land-ice or by floating ice. The "Middle-Glacial" submergence was at first thought to have been accompanied by cold conditions, as the gravels often contained large boulders, and many of the shells were of boreal species; but the idea of a temperate climate during some part of the stage was afterwards propounded to explain the presence of some shells and animal remains which were supposed to indicate a temperature not lower, and perhaps higher, than we have now.

This simpler form of the inter-Glacial hypothesis has been and is still held, though not very confidently, by many British geologists; but it has rarely of late been definitely advocated. Difficulties in applying it became apparent wherever the drifts were closely studied, and led to many modifications and amplifications of the scheme, such as those proposed by SEARLES V. WOOD and his co-workers in the eastern and northeastern counties. Later, PROF. JAMES GEIKIE, in his well-known writings on the subject, suggested a more elaborate classification and correlation, in which several alternations of glacial and inter-glacial conditions were postulated; but his scheme has been practically neglected as unworkable by British glacialists, except that it has been recently applied to some extent by PROF. F. J. LEWIS in his botanical researches in the peat-beds of Scotland and the North of England. These deposits, however, we have been accustomed to class as post-Glacial.

While there has been very little recent expression of opinion respecting the application of the inter-Glacial hypothesis to Britain there is still, probably, a general leaning toward the view that some interruption in the glaciation of our islands did occur. At the same time it is now admitted by most of the field-workers that the supposed "inter-Glacial" gravels are of fluvio-glacial origin, and that the evidence of a warm period separating two distinct and independent glaciations is vague and elusive.

For my own part, although I began work on British drifts some thirty-five years ago with the impression that the inter-Glacial hypothesis was firmly established, and therefore with a decided predilection in its favour, I found myself becoming more and more sceptical of its validity as my field-investigations in various widely separated parts of our Islands proceeded. The cumulative effect of all the evidence known to me has been to bring me to the opinion that the great ice-sheets held their ground in the basins surrounding our islands throughout the deposition of the drift-series, and that the supposed inter-Glacial deposits are indicative only of marginal fluctuations and of the independent culmination of separate lobes during the long period of glaciation.

There is, indeed, one deposit among those which I have examined, and only one, which at first sight seems to suggest inter-Glacial conditions. This is the estuarine silt or warp of Kirmington in North Lincolnshire, at from 60 to 80 feet above present sea-level, which, as mentioned in my previous address, is closely associated with true Glacial deposits, and marks a pronounced alternation of some kind.[1] The presence of estuarine conditions at this spot is difficult to explain on any hypothesis, but particularly so if we suppose the whole country to have been ice-free at the time; and my former suggestion that the deposit was probably accumulated in an inlet between the bare land on the west and the temporarily receding ice-front on the east, still appears to be the most feasible, and has been strengthened by re-examinations of the section. My reason for mentioning this section particularly is that it affords the best—perhaps the only—example of a deposit with *indigenous* fossils intercalated with the direct products of ice in England, and is the best proof of an interruption in the glaciation, of some local consequence at least. It therefore deserves the scrutiny of any visitor seeking British evidence in support of the inter-Glacial idea.

It is impossible in a short paper of this kind to present an adequate

[1] The most recent description of the Kirmington section is contained in the "*Report of the Committee for the Investigation of the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, etc.*" Rep. British Assoc. for 1904 (1905), pp. 272-274.

MICROCOPY RESOLUTION TEST CHART

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discussion of the mass of scattered evidence on which my opinion is based;[1] but I will attempt briefly to summarize the main reasons that have led me to conclude that the ice-sheets surrounding the British Islands lasted without interruption from the beginning to the end of the glaciation.

1. The British drifts are pre-eminently favourable for study because of the unrivalled length of coast section in which they are exposed. In most other glaciated areas, the investigator has to depend upon sporadic sections and upon the untechnical and usually crude records of borings, together with the more or less ambiguous evidence afforded by topographical features. On the east coast of England alone there are over 100 miles of sections wholly in drift, with 150 miles more in which drift forms a covering to the solid rocks. Similar exposures, though not so continuous, are found all along the eastern, and some parts of the western, shores of Scotland; in Cumberland, Lancashire and Cheshire; in Wales; around the greater part of Ireland, particularly on the eastern side; and around the Isle of Man and many of the western islands. With all this wealth of exposure, we might reasonably expect, somewhere on the coast, to have found definite proof of the postulated warm inter-Glacial episodes; yet, although these hundreds of miles of cliffs have been repeatedly investigated, they have not yielded, so far as I am aware, a single example of the occurrence between the boulder clays of a deposit containing the remains of a contemporaneous flora or fauna indicative of temperate conditions, or of any conditions other than those which we know to accompany the borders of ice-sheets. In fact the only fossils as yet found in the intercalated beds of the coast-sections are the fragmentary derivative shells already discussed. Neither is there any other kind of evidence apparent in these coast-sections on which the inter-Glacial hypothesis can be soundly based. This absence of positive evidence in the best exposures testifies strongly against the hypothesis as applied to the British drifts.

2. Owing to the wide range of diversity in the rocks of the British Islands, it is easy almost everywhere to deduce the general direction of ice movement from the constituents of the boulder clays; and the principal ice-streams have in this way been traced in most parts of the country. The drifts of the low coastal tracts show frequently that the major glaciation was effected by ice which moved inland more or less obliquely from the areas of the present sea-basins.

Before the advent of the ice-sheets these basins were occupied by open seas, as is proved by the occurrence of buried cliffs and shores beneath the

[1] The following publications contain the records of my detailed investigations in several districts: *Drifts of Flamborough Head* (summarizing work in East Yorkshire), Quart. Journ. Geol. Soc., vol. xlvii, 1891, pp. 384-431; and the following official memoirs (Mems. Geol. Surv. Gt. Britian and Ireland), all except the first written in conjunction with colleagues; *Geology of the Isle of Man*, 1903; *Geology of the Country around Dublin*, 1903; . . . *around Belfast*, 1904; . . . *around Cork and Cork Harbour*, 1905; . . . *around Limerick*, 1907; . . . *between Newark and Nottingham*, 1908; . . . *the Melton Mowbray District*, 1909; . . . *around Nottingham*, 1910; . . . *around Ollerton*, 1911. Later official work has been done in Cheshire and North Wales, but the results are not yet published.

drifts, and by the admixture of transported marine detritus in the boulder clays wherever the ice from out of the basins has impinged upon the present land-area. The pre-existing marine deposits of the basins were occasionally swept forward in huge masses, along with similar masses of the underlying rock-formations, but were more frequently disintegrated and dispersed piecemeal among the other ingredients of the boulder clay. From the composition of the drifts we are able, therefore, readily to deduce the condition of the basins at the period preceding the glaciation. It follows that if the basins, after first having been filled with ice, had reverted to their original condition through the influence of a warm inter-Glacial episode, and then for a second time, or more than twice, had been refilled by fresh ice-sheets which again invaded the land, we ought to find as clear evidence for the previous state in the later boulder clays as in the earlier. Even supposing that the basins had remained permanently above sea-level during the interval, they must have received freshwater and land deposits in quantity, which, like the previous marine sediments, would have left their traces in the boulder clays formed from them, since the work of an ice-sheet is merely to amalgamate the material in its path.

No such evidence is to be found in our drifts. On the contrary, even where most complex, as, for example, on the east coast of England, the boulder clays carry proof in their composition that the neighbouring basin was ice-filled throughout the period of their deposition; the shelly fragments and patches of sea-bottom are confined to the lowest boulder clays, representing a single onset of the ice from the sea basin, while the upper boulder clays contain boulders which prove that ice streaming outward from the hill-country in the north of England was blocked on reaching the basin and diverted into a southerly course roughly parallel to the present coast-line. The barrier that caused this diversion could be no other than an ice-sheet in the basin; and the effect of this barrier is very clearly traceable in the composition of every band of boulder clay above the shelly clays of East Yorkshire. That the blockade was continuous right up to the close of glaciation of this district is shown by the abundance of Cheviot rocks in the uppermost ("Hessle") boulder clay. Further proof of the persistence of this condition in the North Sea basin from the beginning to the end of the glaciation is afforded by the drifts of the eastern and northeastern parts of Scotland.

An almost precisely equivalent condition of the Irish Sea basin is demonstrated by the sequence of Glacial deposits exposed in a grand succession of coast-sections, on the one side in Lancashire, Cheshire and North Wales; on the other side, in the east and northeast of Ireland; and, near the middle, in the Isle of Man. In these parts the shelly drift holds a varied position in the series in strict accordance with the local circumstances governing the general glaciation, but indicates no more than a single invasion of the old sea-floor; while the deposits, from bottom to top, are explicable only on the supposition that the ice-block in the basin lasted until the uppermost Glacial deposits were accumulated.

3. That there were minor vicissitudes during the long glaciation, causing

fluctuation of the ice-margins and local changes in the direction of the flow, is clearly recognizable in the composition of our drifts; but I can find no evidence that any one of these vicissitudes affected the whole of the British glaciated area simultaneously, or reached the proportions in time and space postulated in the inter-Glacial hypothesis. I purposely leave out of account the question whether the small local glaciers, indicated by the latest moraines in a few mountain-valleys of Scotland, Ireland and the Lake district were the lingering relics of the great glaciation, or were separated from that period by an interval of complete deglaciation, as it is fully realized that the geographical position of our islands is such that comparatively slight meteorological changes would suffice again to produce small glaciers in some of our mountainous districts. The hypothetical changes required to melt out and then to restore the great ice-sheets that occupied the basins surrounding Britain are of an altogether different order of magnitude, and must, I think, have left plenty of evidence if they had really occurred.

It has been urged that all or nearly all traces of older glaciations may have been destroyed during later inter-Glacial and Glacial stages; but in the Midland and Eastern counties of England the existing drifts frequently overlie Mesozoic and Tertiary clays and sands that are fully as perishable as the drifts themselves; and in many sections the Glacial deposits comprise several different bands of boulder clay, with alternations of sand and gravel, proving that in this as in other areas of low relief toward the margin of ice-sheets, the predominant effect of glaciation was to cover and protect rather than to destroy. Moreover, both in Norfolk and in East Yorkshire the beds below the lowest boulder clay contain evidence of the beginning of Glacial conditions and are, to all appearance, the original base of the Glacial sequence; while there is no recurrence of similar beds at higher horizons.

4. In this discussion my opinion adverse to the inter-Glacial hypothesis in its application to British drifts depends entirely upon my personal examination of the field-evidence; and I do not desire to lay stress upon merely theoretical considerations. Nevertheless, I think that even on theoretical grounds, the balance tells against the likelihood of more than one great ice-sheet having covered the low basins of northwestern Europe during Pleistocene times.

As I have repeatedly urged in previous papers, the glaciation of the greater part of Britain and Ireland depended hardly at all upon the snow that fell upon high land, but almost entirely upon the snow that fell upon the broad surfaces of the ice-sheets themselves. As in Scandinavia and the Baltic, so also in the British Islands, the icesheds during the major part of the period were quite independent of the present watersheds, and in many places rose much higher than these. There is direct evidence in the Isle of Man, and confirmatory evidence in the east of Ireland and the northwest of England, that the "West British" ice attained in its central part an altitude of at least, over 2,000 feet above present sea-level, and may have approached 3,000 feet. The height of the "East British" ice over the middle of the North Sea basin is less directly indicated; but that it is likely to have reached a similar magnitude is implied by the extent of its splay over the eastern counties of England. These masses differed essentially from mountain-fed glaciers; in having practically no higher reservoirs to draw upon for their sustenance; and their history under vicissitudes of climate must have been entirely different. Severe climatal conditions must have been required for their initiation and early growth; but when their full dimensions were attained and their snow-covered domes rose up to between 2,000 and 3,000 feet above the basins, they could be sustained in these northern latitudes, and even augmented, under an amelioration sufficient to bring a return of mild climate to any bare land of low elevation in the same latitudes.

There must, then, have been a very lengthy lag in the disappearance of the ice-sheets after the amelioration of climate set in, and a corresponding lag in their rebirth and regrowth if the severe conditions had returned after an inter-Glacial period of warmth. Consequently, even if the climatal changes were rapid, the time required to complete a cycle of deglaciation and reglaciation in these northern latitudes would be very long. Any such lengthy interval could not fail to leave conspicuous evidence, both stratigraphical and physiographical, in a marginal area like the British Islands, where its maximum duration would be attained. If such evidence had existed, it must have become apparent to every careful field-investigator of the British drifts. Far otherwise is the case; and I shall venture to state, from my knowledge of contemporary research in this country, that if the inter-Glacial hypothesis had not come down to us by inheritance, it would not have arisen spontaneously from any recent work.

5. Every increase in our knowledge of the conditions in [illegible]tic and Antarctic lands brings out more strongly the fact that the lo[illegible]tion and extent of the existing ice-sheets is determined by the amount of precipitation of snow or frozen vapour, and that there are many areas of bare land where the cold is no less severe, indeed sometimes more severe, than on the ice-fields. One cannot doubt that a somewhat warmer climate in these regions if accompanied, as is likely, by increased precipitation, would bring about an actual extension of the present land-ice. Within certain limits, fluctuations of temperature are of little consequence as compared with fluctuations of snowfall; and the latter may cause oscillations of ice-margin contrarywise to the changes of actual temperature. The growth of a great ice-sheet must itself have a progressive influence upon the local conditions of weather, which in turn have their reaction through increased or diminished snowfall. Hence the expansion or contraction of the limits of glaciation does not necessarily imply secular changes of climate, but may be due to strictly localized circumstances.

For such instability of the ice-margins in Britain during the Glacial period there is plenty of evidence. Moreover, some of this evidence implies that the Eastern and Western sheets did not attain their maxima simultaneously, but successively; the East British ice having shrunk considerably while the West British ice was still extending its borders. But every attempt to explain the phenomena by the application of the inter-Glacial hypothesis has proved hopelessly confusing, and has introduced difficulties and complexities of classification for which, in my opinion, there is neither warrant nor necessity.

Bearing in mind the inexhaustible possibilities of our drifts, and being aware of some anomalies not fully understood, I am ready to grant that new evidence may yet be found to re-establish the inter-Glacial interpretation in Britain. Meanwhile, in the light of present knowledge, there appears to be no valid reason for supposing that our islands have been more than once enwrapped by ice-sheets, however the case may stand in other countries.

AN ESTIMATE OF POST-GLACIAL AND INTER-GLACIAL TIME IN NORTH AMERICA.

BY

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INTRODUCTION.

Various attempts have been made both in Europe and America to estimate the length of time since the Pleistocene ice-sheets departed, but the results obtained by no means agree. Probably the most accurate chronology is that worked out skilfully and patiently by Baron De Geer and his assistants from the terminal moraines and related marine clays of southern Sweden. To his estimate of 12,000 years must of course be added the time required for the retreat of the ice from Germany across the Baltic, which would certainly add some thousands of years and perhaps double the total.

In America estimates of post-Glacial time have been made chiefly from the recession of waterfalls. The falls of St. Anthony on the Mississippi, for example, were estimated 30 years ago by N. H. Winchell to have required 8,000 years to do their work. In 1908, however, F. W. Sardeson discovered new factors and lengthened the time, suggesting 30,000 years as more probable.[1]

Most attention has naturally been given to Niagara Falls, which has cut its way back for more than six miles from the escarpment at Queenston Heights, and guesses and estimates of the time required have been made by various geologists from Lyell in 1842 to the present time. It is known that the falls have been receding at the rate of four or five feet a year since the first surveys were made. The latest estimate of the rate, made by Dr. Spencer, gives 4.2 feet per annum.[2] It seems an easy problem to solve by dividing 4.2 into 6½ miles reduced to feet. In reality the problem is so complex and hard to interpret that different students of the subject give results ranging from 7,000 to 40,000 years, the latest estimate, that by Dr. Spencer, being 39,000 years.[3]

Niagara has proved a very uncertain chronometer because of the great variation in the volume of water at different stages in its history.

It is intended in this paper to present an independent method of deter-

[1] Bull. Geol. Soc. Am., Vol. XIX, pp. 29-52.
[2] *Evolution of the Falls of Niagara*, p. 38.
[3] Ibid, p. 370.

mining the length of post-Glacial time, in which wave action will be used as a chronometer instead of falling water. The basin of Lake Ontario has been occupied by water at various levels ever since the ice departed, and as the area of water has undergone little change and the shores cut by the waves have been of the same character, the work done should be fairly uniform. It is intended later to compare post-Glacial with inter-Glacial work so as to form an estimate of inter-Glacial time.

WATERS WHICH HAVE OCCUPIED THE ONTARIO BASIN.

The basin of Lake Ontario was freed from ice long before the Wisconsin ice-sheet had melted from the St. Lawrence valley, so that the basin filled to a point much above its present level and overflowed eastwards past Rome, N.Y., into the Hudson. Lake Iroquois, which was thus formed, lasted long enough to form shore cliffs and gravel bars as strong and mature as those of Lake Ontario, so that the two lakes must have required about the same length of time to do the work.

After the ice dam left the St. Lawrence valley there was a time when the Ontario basin was below sea-level, though there is no evidence that the water was salt. There are beaches at various levels corresponding to this stage, but none of them are as well formed or continuous as those of Lake Iroquois or Lake Ontario.

Lake Ontario began when the upwarping of its outlet raised the Thousand Islands region above the sea, and the differential elevation toward the north-east has now progressed so far that the lake stands 245 or 246 feet above sea-level. Whether the outlet is still rising very slowly or not is a disputed question. With the uplifting of the outlet, the surface of Lake Ontario has been backed up toward its southwest end, and there is evidence that the water has gradually risen at least 75 feet and probably 100 feet in the neighbourhood of Toronto.

The Iroquois beach is deformed in a similar way but to a greater extent. Probably the motion was at first more rapid, and the deformation of the older beach, of course, sums up the effects of all the elevation from its beginning onwards. It now stands from 116 to 495 feet above Lake Ontario. It will be evident that, with this rise of the waters toward the southwest, wave action must have attacked promontories progressively at higher and higher levels, thus producing a submerged inclined plane. With the attack upon the promontories went also the transport of materials building up bars across the mouths of bays.

The rate of attack on the promontories of boulder clay which make up much of the shores of lakes Iroquois and Ontario must have been fairly uniform, and the rate of building the sand bars must have progressed in a corresponding way.

RECESSION OF SCARBORO HEIGHTS.

Farmers along the Scarboro cliffs, which rise from 100 to 350 feet above Lake Ontario, have long noticed that their fields were being encroached on by the undercutting of the waves and also by the carving of ravines by rain action, but until recently no estimate of the rate of recession has been made.

Surveys of the Scarboro shore were made as long ago as 1792, but the work was roughly done and the results are too uncertain to be of much value. In 1862 and 1863 the township was carefully re-surveyed by Mr. F. F. Passmore, who planted corner stones to fix the road allowances and the boundaries of properties. Toward the end of 1912, 50 years later, another careful survey of the cliffs was made by Messrs. Speight and VanNostrand on instructions from Mr. R. C. Harris, Commissioner of Works for the City of Toronto, to determine the rate of recession of the cliffs. It was proposed to make a pumping station and reservoir near the highest part of the cliffs, and it was necessary to know how secure the site might be.

Messrs. Speight and VanNostrand ran 17 lines from the various corner stones to the edge of the cliff and these have been compared with Mr. Passmore's results. The recession at the 17 points, beginning at the southwest, works out as follows: 8, 98, 93, 120, 85, 55, 198, 31, 76, 50, 167, 199, 127, 128, 62, 39, 89 feet. If the average of the 17 determinations be taken the recession during the 50 years is 96.2 feet, which equals 1.92 feet per annum. In considering the field results it appears probable that the first determination, 8, should be thrown out, since it is on comparatively low ground at the southwest end of the cliffs. The three largest figures 198, 167 and 199, were found at points where ravines are being rapidly cut back, and they should be left out of the calculation also.

The other 13 measurements may perhaps be accepted as representing the normal rate of erosion; though two of them, 127 and 128, were at points where incipient ravines occur, making it doubtful whether they should be used or not. Assuming the 13 measurements to be normal, the average rate of erosion in 50 years is 81 feet, which works out to 1.62 feet per annum. If the two highest numbers, 127 and 128, are omitted as being doubtful, the average rate of erosion in 50 years is 72.54 feet, or 1.45 feet per annum.

The next point to determine is the total amount of recession since the waves of Lake Ontario began their work, a point which at first glance might seem very problematical, but which really proves fairly definite. Soundings made off Scarboro heights to determine the location of a new intake for the waterworks show a gentle slope lakewards for 13,000 feet until a depth of about 100 feet is reached. Beyond this the contours are crowded together and the depth increases rapidly to 175 feet. It appears that the southward extension of Scarboro heights ended there and that wave erosion began when the level of Lake Ontario was about 100 feet lower than at present. The very gentle slope of 100 feet in 13,000 apparently corresponds to the slow rise of the water as the cliff was cut back. If it had not been for this rise of water the work of undercutting the cliff would probably have grown slower and slower as the shore receded, but this seems to have counterbalanced the hampering effects of shoaling water.

If the rate of recession worked out for the last 50 years has held from the beginning at 1.62 feet per annum, the 13,000 feet have required 8,000 years;

and at the slower rate of 1.45 feet per annum this would be lengthened to nearly 9,000 years.

It is probable that Lake Ontario began its existence at a still lower level and at a greater distance than 13,000 feet from the present cliffs; but this earliest stage has not been certainly demonstrated. We may look on 8,000 years as a minimum age for the lake, with a probability that it has lasted for a considerably longer time.

THE BUILDING OF TORONTO ISLAND.

Toronto is near the southwest end of Lake Ontario, with a reach of 140 miles toward the east and less than 40 toward the southwest. Under these conditions the most effective wave transport will evidently be southwest-

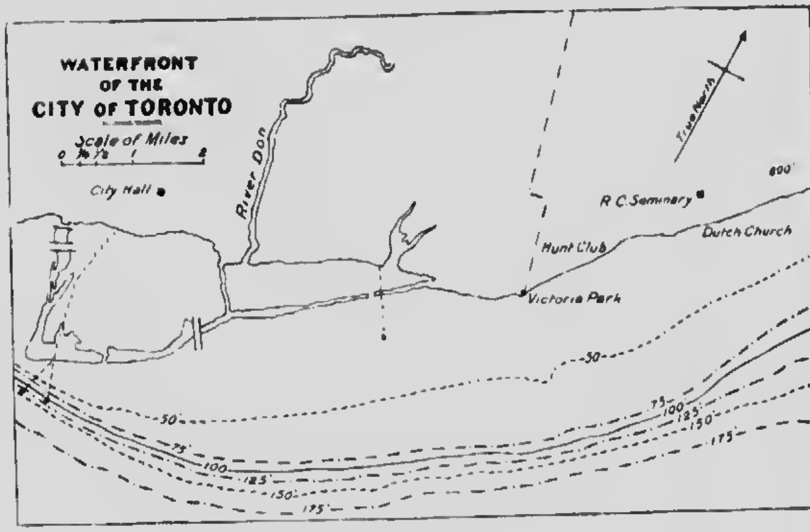

FIG. 1.

ward during easterly gales. As Scarboro cliffs were undermined the clay would be removed by the undertow and the coarser materials, sand and gravel, would be transported southwestward alongshore, ultimately building a spit across the mouth of Toronto bay. This mode of operation was observed by Sir SANDFORD FLEMING as early as 1850 and was excellently described by him at that time.[1] His diagrams show a succession of stages in the destruction of a Scarboro promontory, with the corresponding growth of a spit to the southwest, ending with a map of the spit, or hook, and of the harbour in 1850. He added another diagram suggesting the probable future arrangement, which quite closely represents the present conditions 60 years later, if one omits the changes caused by man's work. Recent soundings

1 Jour. Can. Inst., 1851, pp. 107 and 223.

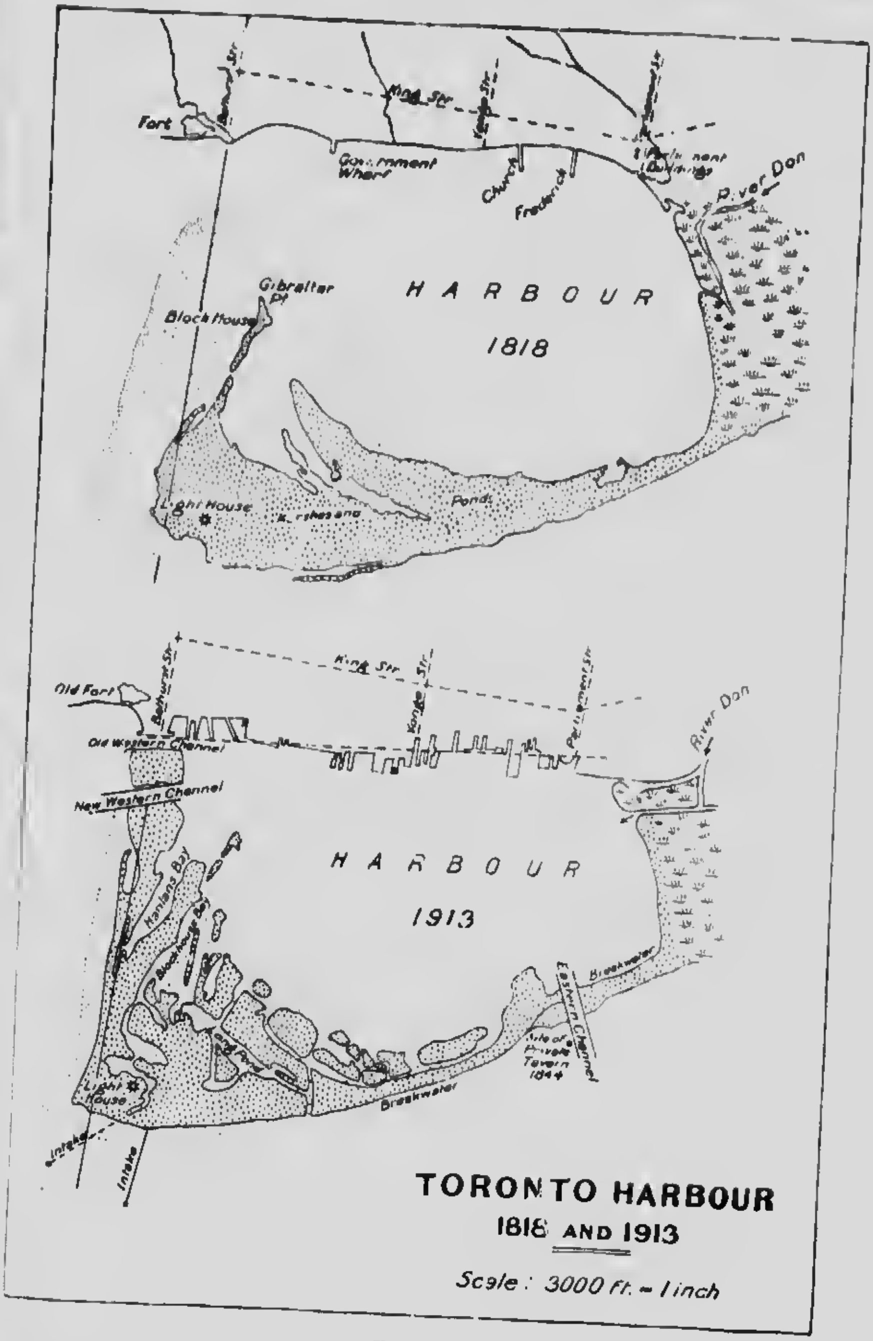
Fort
King Str.
Government Wharf
Church
Frederick
River Don
HARBOUR
1818
Gibraltar Pt
Block House
Light House
Ponds
Old Fort
Old Western Channel
New Western Channel
King Str.
Yonge St
River Don
HARBOUR
1913
Breakwater
Eastern Channel
Breakwater
Intake
Intake
TORONTO HARBOUR
1818 AND 1913
Scale: 3000 ft. = 1 inch

Fig. 2.

show that the Scarboro promontory extended farther south than his diagrams represent, but otherwise his work could hardly be improved upon, except in details.

Toronto harbour, one of the best on the lakes, has been of interest ever since vessels began to ply on Lake Ontario, and has been surveyed a number of times from 1816 to the present. Four of these maps (1818, 1841, 1882, 1911) have been reproduced in a recent report of the City Commissioner.[1]

The sand and gravel advancing southwestwards from Scarboro heights form a bar running nearly straight for six miles and then bending suddenly north for nearly two miles. The so-called island is really a succession of hooks extending westwards, with shallow lagoons between.

The regularity of the work has been interfered with by the delta of the small river Don, which cuts the enclosed body of water in two, forming Ashbridge's bay to the east and Toronto bay to the west. During the known history of the harbour the continuity of the bar has been broken by storms at one point, making a shallow eastern channel into the bay, and the breach has later been repaired with materials advancing from the northeast. The eastern outlet to the harbour was found useful, and in 1900 the channel was dredged out and protected on each side by cribwork extending southeast for 1800 feet, where soundings show a depth of 12 feet.

It is evident that the eastern crib must interrupt the normal southwestward movement of the sand. The result of this has been to build up a triangular area of sand along the shore east of the crib. In 1910 the area of sand exposed had grown by 17 acres, as reported by Mr. J. G. Sing, government engineer in charge; and in 1913 a rough survey made by myself showed an increase to 22¾ acres. From soundings made before the pier was built it is known that the average depth of water was four feet, and the sand rises now on the average one foot above water, giving a thickness of five feet for the sand accumulated in 13 years over the area now dry land. This works out to 14,060 cubic yards per annum. The land area is built up to a width of 600 feet on the east side of the cribwork, but the crib extends to 1,800 feet in all, where it reaches a depth of 12 feet of water. The part under water also must have arrested a large amount of sand, though there is no way of measuring up the exact amount with our present data, since there are no recent accurate soundings to show how much the water has shoaled during the 13 years. It is known that some sand passes the southern end of the cribwork in deeper water, since dredging is necessary to keep the proper depth of the channel, but the amount is uncertain. Probably the thickness of sand set in motion diminishes rapidly with the depth, and it may be assumed that the sand moved westward below water is not more than twice the amount proved to have been deposited on the area of new made land. Making this assumption, 42,000 cubic yards of sand are moved per annum.

Surveys of Toronto island and soundings of the waters around it, com-

[1] *Report of the Board of Commerce on Toronto Waterworks*, 1912.

bined with the results of bore-holes showing the depth of the sand, provide means of estimating the cubic content of the structure. The average depth of the sand is 107 feet and an estimate of the total bulk of the island foots up to 337,000,000 cubic yards. This is probably not over the mark and may be considerably under it. Divided by 12,000 this gives in round numbers 8,000 years.

In this estimate no account has been taken of the large amounts of sand in the shore deposits along Ashbridge's bay to the east of the island. If these are included, the time will be greatly lengthened. It must be admitted that the result just given is far from certain, since 13 years is a short period of time from which to determine the rate of transport of the sand, and the amount of sand transported under water may be greater than has been assumed. At some time in the future the work may be repeated with more exact data, giving greater certainty than can be expected from the present rough estimate.

LENGTH OF TIME SINCE THE ICE RETREATED.

Of the two methods of estimating the age of Lake Ontario employed above, the one from the recession of Scarboro heights is decidedly the more accurate, but as the two results are much the same, the estimate formed from the rate of growth of Toronto island may be looked on as strengthening the first estimate of 8,000 or 9,000 years.

As mentioned before, the Iroquois beach at Toronto is about equal in maturity to the Ontario beach. This may be seen from shore cliffs cut in boulder clay in the northern part of Toronto and at Scarboro, and also from a study of the great hook-shaped gravel bar of Lake Iroquois in East Toronto, which has about the same size and shape as Toronto island, with a thickness of at least 100 feet. The wave work of the two lakes in the vicinity of Toronto, as estimated above, demands therefore 16,000 or 18,000 years. This does not, however, include the whole history of either lake. There is evidence at the Burlington gravel bar near Hamilton that Lake Iroquois began its work at a point 100 or more feet lower than the top of the bar. The East Toronto gravel bar, and the shore cliffs cut in boulder clay to the east and west of it, represent only the later work of Lake Iroquois. The earlier stages of much lower water must have required a large additional time.

In the case of Lake Ontario also, there must have been an early low-water stage before the water rose sufficiently to attack Scarboro heights and build Toronto island. This is proved by the fact that Lake Ontario began at sea-level and was gradually raised to its present height of 245 feet by the differential uplift of its outlet. How long a time should be allotted to these early low-water stages of the two lakes it is not easy to say; but they were probably much shorter than the well recorded later stages.

There is another episode of great importance to be considered, that of the marine stage which intervened between Lake Iroquois and Lake Ontario. The time required for it is difficult to estimate. When the glacier began to withdraw from the northern side of the Adirondack mountains in New York state there were spillways opened between the ice and the rocky slopes to the south, permitting an outflow at lower levels than Lake Iroquois, but these water levels were probably quite evanescent as compared with Lake Iroquois itself and have not left well marked beaches. Still later, a way was opened past the Adirondacks to the St. Lawrence valley at a time when the whole region stood much lower than now, and there was a continuous water level between the Ontario basin and an extension of the Gulf of St. Lawrence. This has been named by Prof. FAIRCHILD Gilbert gulf and is supposed by him to have been salt water with a wide channel in the Thousand Islands region. It is probable, however, that the channel was narrow, at least in early stages, with ice as its northern shore, since after careful search no beaches have been found where the shore should have been. This is corroborated by the entire absence of marine shells from the Ontario basin, though they are plentiful from the Thousand Islands eastwards. The sea-level stage should be called Gilbert lake rather than Gilbert gulf, since the great river or rivers entering it kept the water fresh.

In the Province of Ontario there are well formed beaches on the north side of the basin from Newtonville to the Bay of Quinte, near Kingston, the highest rising 127 feet above Lake Ontario; and there are beaches with marine shells east of Brockville 85 feet above it. In the State of New York a beach on one of the Thousand Islands reaches 140 feet.[1] Farther northeast, at Montreal, there are marine beaches reaching 560 feet above the sea, or 324 feet above Lake Ontario, but the difference is accounted for by the strong northeasterly elevation of that part of the continent.

During the marine episode deposits of sand and clay more than 100 feet thick were formed in eastern Ontario, and there was an elevation of 85 feet or perhaps 140 feet in the Thousand Islands region. There were well formed beaches as well as thick sedimentary deposits made during this time and important crustal movement took place; but there is no means known at present by which to estimate accurately the amount of time required. It could not have been less than some thousands of years. Four thousand years, or half the time required by Lake Ontario to do its work, may not be an unreasonable guess for the marine stage.

Summing up the whole matter, one begins with the most accurate estimate, that of 8,000 or 9,000 years for the recession of Scarboro heights, supported by the rate of building of Toronto island. To this must be added as many more years for the later stages of Lake Iroquois, which did an equivalent amount of work. For the earlier phases of these two lakes and for the marine interval one can only guess the time. It is probably not unreasonable to suggest 8,000 or 9,000 years, as in the former cases, making in all 24,000 to 27,000 years for post-Glacial time. This is much less than Dr. SPENCER's estimate of 39,000 years for the work of Niagara Falls, but agrees fairly well with TAYLOR's estimate of 25,000 or 30,000 for Niagara; it also agrees with FAIRCHILD's estimate of 10,000 years for Lake Ontario and 30,000 years in all since the ice left the Lake Ontario region in New York.

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[1] Rep. Bur. Mines, Ontario, Vol. XIII, Pt. 1, 1904, pp. 238-243.

It is believed that the time estimates from Scarboro and Toronto island and from the Iroquois beach are a trustworthy as that from Niagara Falls, but that the uncertainty as to the time to be allotted to the early lake and marine episodes seriously lowers the accuracy of the total SARDESON'S guess of 30,000 years for St. Anthony falls corroborates the result.

The 12,000 years obtained by DE GEER for Sweden cannot really be compared with the time at Toronto, since the distances from the glacial centres are so different in the two cases. The distance of retreat to the ice-shed as shown on DE GEER'S map is about 600 kilometres or 370 miles;[1] while Toronto is twice that distance from the Labrador glacial centre.

DE GEER finds 5,000 years for the retreat of 370 miles, and 7,000 for the time since the disappearance of the ice. If we double the length of retreat we add 5,000 years more, giving 17,000 years in all, very much less than the figures given above for Toronto. The time needed for the retreat from north Germany should of course be added in comparing with American conditions.

The estimate of post-Glacial time in the Alps given by PENCK is from 30,000 to 50,000 years, which corresponds more closely to the results obtained in America.

LENGTH OF THE TORONTO INTER-GLACIAL PERIOD.

The Toronto inter-Glacial formation has been studied for many years, and has been described a number of times[2] so that a detailed account of it is not required here. The most recent description will be found in brief form in the guide book to the geology of Toronto prepared for the present Congress. In this paper it is intended to bring together the points which have a bearing on the length of the inter-Glacial period, comparing them particularly with the estimate of post-Glacial time just given.

The Toronto formation is the earliest and much the mo t important of the known inter-Glacial periods of Ontario. Its deposits rest upon the earliest sheet of till, where that had not already been eroded away, and are covered at Scarboro heights by a complex of four later till-sheets separated from one another in each case by from 25 to 40 feet of stratified sand and clay. It seems to correspond in position to the Aftonian beds of Iowa and contains some of the fossil mammals described from that formation. It is almost certainly of the same age as inter-Glacial beds at Cayuga lake in New York state and near Lake Erie, and also of the same age as the wide spread inter-Glacial brown coal deposits along the rivers flowing into James bay.

The interval was characterized by a climate decidedly warmer than at present, as was shown by the late Professor PENHALLOW from the leaves and wood of forest trees from the Don. The materials have been gone over very carefully within the past year by Mr. J. H. WHITE of the Forestry Department of the University of Toronto, who in the main corroborates PEN-

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[1] Compte Rendu, Cong. Géol. Intern., XIe Session, p. 255, (plate 1).

[2] G. J. HINDE, Can. Jour., 1878, p. 388, etc.; also A. P. COLEMAN, Jour. Geol., Vol. IX, 1901, pp. 285-310; and *Interglacial Periods in Canada*, Compte Rendu, Congrès Géol. Intern., Xe Session, 1906.

HALLOW'S opinion, and suggests a climate corresponding to that of southern Pennsylvania. The assemblage of about 30 trees, including osage orange, locust, hickory, etc., implies long dry summers with shade temperatures reaching 90° or 100° Fahr., corresponding to a latitude four degrees south of Toronto.

EVENTS OF THE TORONTO INTER-GLACIAL PERIOD.

The earliest part of the inter-Glacial period, when there must have been a glacial lake corresponding to Lake Iroquois in post-Glacial times, has left no record. The inter-Glacial drainage had a base-level as low as Lake Ontario, when a small stream, probably not unlike the present Don, cut a channel 200 paces wide through boulder clay and then 16 feet into the underlying Lorraine shale. The vertical walls of shale are about as high as those of the present cuttings of the Don, and it is reasonable to suppose that as much time was required to do the work, say 8,000 years.

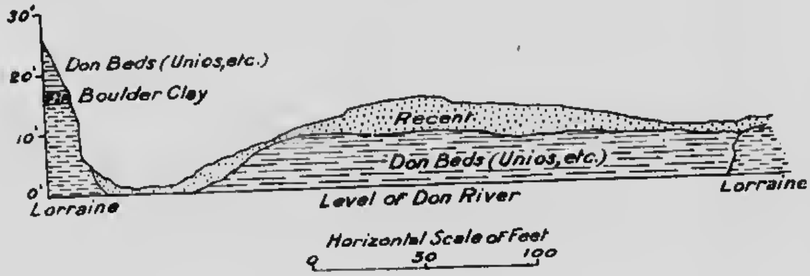


FIG. 3.—Section at bend of Don.

The river occupying this valley deposited coarse shingle on the bottom, mixed with branches and trunks of red cedar, elm, oak and pawpaw, so that the climate was already warmer than at present, since the pawpaw does not reach the north shore of Lake Ontario now. The water level of the inter-Glacial lake then rose to 60 feet above the present, for what reason is unknown unless its outlet was warped up. Forty-five feet of Don beds were laid down, including several thin or thick beds of stratified clay with interbedded sand and fine gravel. The uppermost four feet of sand are reddened and cemented with iron oxide, implying a long period of oxidation. Trunks of trees are found at the bottom of the beds, and leaves as well as trunks and branches occur at various levels above. How much time should be allowed for the growth of the elms, oaks, maples, sycamores and other forest trees one can only guess. The trunks at the bottom must have been hundreds of years in growing, and those at higher levels as well as the oxidation of the upper sand must have demanded other hundreds of years. A thousand years for the whole Don period is a very low estimate.

There was another rise in the inter-Glacial lake to a height 150 feet above the present Ontario and a bay stretched for 14 miles or more to the north of

Toronto, where a large river entered, draining the valleys of the present Upper Lakes. During the Scarboro period this river deposited a delta upon the Don beds just described. The peaty stratified clay and sand of the delta have a breadth of 18½ miles and a known area of 60 square miles. Before Lake Ontario cut back Scarboro heights for two and a half miles, the area must have been much more extensive.

At one section of the peaty clay 672 layers have been counted in 19 feet 6 inches, each consisting of a whitish silty part and a darker clayey part. If these are annual layers, as seems certain, the whole length of time required for the 92 feet of clay at Scarboro was probably at least four times as much, or about 2,700 years.

The 60 feet of stratified sand which follow the clay were probably laid down in shallow water at a faster rate. At the moderate estimate of one foot in ten years over the many square miles of the delta this would require 600 years.

Adding up the amounts given above for the different deposits of the Toronto inter-Glacial formation the total is 4,300 years.

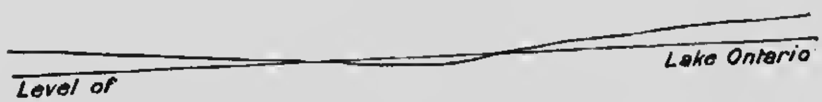
Eighty feet of thickly bedded sand and gravel formed by a powerful inter-Glacial river in the western part of Toronto are not included in this estimate, since their relations to the other beds are not clear. They were formed probably either before or after the events mentioned above and so may increase the allotted time.

After the Scarboro delta was formed the inter-Glacial lake was drained, probably by the sinking of its outlet, so that river valleys could be cut through the sand and clay. Three of these valleys are known, one several miles wide, in the Humber region to the west of Toronto, another about five miles wide from Highland creek to Rosebank, and a valley only a mile wide at the "Dutch Church," Scarboro heights. The two wide valleys appear to have been formed on the two sides of the former delta and may not have been very deep, though their relationships have not been worked out very certainly. The Dutch Church valley is beautifully exposed in cross-section in the cliffs at Scarboro, so that its character is well known.

The inter-Glacial stratified clay and sand rise to about 150 feet above Lake Ontario on each side of the ancient valley, and a well sunk at the Dutch Church showed that the boulder clay filling the valley goes 16 feet below the lake. The valley was 166 feet deep and 1,100 feet wide at the level of Lake Ontario, with gentle slopes on each side to the top of the inter-Glacial beds, where the width is about one mile. The valley seems to have been cut by a small stream, which would probably work fairly rapidly through the upper sandy beds but very slowly through the tough stratified clay, over which small modern streams tumble as cascades. As the stream deepened its channel, the action of rain and weather beveled the sides of the valley to their present slope of 150 feet in 2,000 feet or one foot in 13 on the average. The valley was far more mature than any carved in the Toronto region in post-Glacial times. Tributaries of the Don which began their work at the Iroquois stage and have continued it during the life of Lake Ontario have sometimes cut short ravines to a depth of 150 feet, with rounded surfaces in the upper part and steep walls at the bottom. The width is only a few hundred yards and the average slope of the lower part about 1 in 2 or 3 and of the upper part 1 in 4 or 5. They have decidedly the look of immaturity. If the Don and its tributaries have been at work, as estimated on earlier pages, for 24,000 or 27,000 years, the Dutch Church stream must have required at least twice as long, say 50,000 years to shape its valley with sides sloping only 1 in 13, and the actual time may have been very much longer.

Section of Don valley; narrow part.

Section of Don valley; wide part.



Section of inter-Glacial valley; Dutch church.

Fig. 4.

The period of low water probably came on gradually by the lowering of the outlet of the basin, and doubtless the early stages of erosion of the delta were carried on with quite gentle drainage slopes and at a very moderate rate.

In the sketch of inter-Glacial phenomena just given an attempt has been made to estimate the probable length of time required for each operation recorded, resulting in a total of 62,000 years or more; but no estimate has been made of early and late parts of inter-Glacial time, which have left no record. The record begins with the carving of a valley in Lorraine shale in the same way as rivers flowing into Lake Ontario are now doing; but there must have been a high-water stage at the beginning of the inter-Glacial time corresponding to Lake Iroquois in post-Glacial history, which would lengthen the total by perhaps 8,000 years; and there must also be an important gap at the latter end, where the record proves low water in the Ontario basin, for the advancing ice-sheet of the next glacial invasion must have obstructed the St. Lawrence outlet, reversing the processes described in the retreat of the ice in post-Glacial times. If these be taken into account the duration of the Toronto inter-Glacial interval should be greatly lengthened, probably to 100,000 years or more.

Post-Glacial time, which has lasted at least 24,000 years, probably includes less than one-third of the stages recognized in inter-Glacial time; and it may be that we are now entering upon the long central portion of another inter-Glacial cycle.

In the foregoing estimate of the duration of the Toronto inter-Glacial period no consideration has been given to two factors which add to the impression of its length. These are the climatic changes and the changes of level of the land. The climatic cycle runs from glacial conditions to a warm temperature stage and then back again to permanent ice. The change is equivalent to a shifting of latitude of no less than 25°, say from Ohio to Greenland. No matter what theory of the causes of glacial periods be adopted, the change of climate must go on slowly. Since historic times there has been no well marked variation in Europe, and one cannot transform a climate with a freezing summer temperature into one with 100° Fahr. in the shade without plenty of time for the operation.

Again the rise and fall of the land due to epeirogenic causes appears to to be extremely slow, and there is positive proof of differential elevation to the extent of at least 166 feet during the Toronto formation. The rise of 166 feet in the earlier part of the inter-Glacial period, the halt at the maximum point, and the sinking once more to the original level could hardly have been accomplished in any short period of time. Changes of level on so large a scale appear to require many thousands of years. It is probable that the downward shifting of level is to be accounted for by the load of ice, and the rise by the melting of the ice removing the load, but the adjustment in both cases may have lagged thousands of years after the change of load. This has certainly been the case in post-Glacial times.

EXTENT OF THE INTER-GLACIAL DEPOSITS.

The known extent of the inter-Glacial delta deposits at Toronto is 60 square miles, with a probable area very much larger than this; but one would expect that deposits of the same age, but perhaps on a smaller scale, should occur in other places round the Ontario basin. The inter-Glacial river flowing from the north was probably much the largest entering the lake, but other deltas must have been formed by smaller streams. The most important find of the sort is described by Miss C. J. Maury near Cayuga lake in central New York, where inter-Glacial materials contain many shells such as *Unios*, *Anodons*, etc. Comparing them with the shells of the Don valley no less than eleven species, more than half of those found, occur also in the Don beds. The plant remains unfortunately are too poorly preserved for identification. It is noteworthy that these inter-Glacial beds are at about the same level as the Don beds, and that the shells are largely forms belonging to Mississippi waters.[1]

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[1] Jour. Geol., Vol. XVI, 1908, pp. 565-7.

Mr. Frank Collins Baker refers also to a leaf of willow in inter-Glacial beds in Watkins Glen, which may correspond to the willow leaves obtained from the Scarboro or cool climate beds.[1]

Peaty matter with beetles' wings has been found by Dr. Hinde and myself in a section on the shore of Lake Erie at Cleveland. It is of exactly the same character as the Scarboro materials, and out of the four extinct beetles obtained there, two occur at Scarboro also, making it certain that the deposits are of the same age.

OTHER INTER-GLACIAL DEPOSITS PROBABLY OF THE SAME AGE.

The most important inter-Glacial deposits in the United States are the Aftonian beds of Iowa and adjacent states, lying between pre-Kansan and Kansan sheets of till. The Aftonian is the oldest of the American inter-Glacial periods and corresponds in position to the Toronto formation, which has one till below it and four above. Many localities are known for the Aftonian in various parts of Iowa and in Nebraska and South Dakota, along both the Missouri and Mississippi rivers. The fossils include leaves and wood of a number of trees such as pine, elm, oak, ash and hickory, but the species have not been certainly determined. The genera nearly all occur in the Don beds. The mammals have been studied more carefully and cover a wider range than those of Toronto. They include mammoth and mastodon, a large bear, a deer like the Virginia deer, and *Cervalces*, all of which may be the same as the Toronto species;[2] but *Mylodon* and the extinct horses of the Aftonian have no corresponding forms at Toronto.

Dr. Calvin and other geologists state that the climate was at least as mild as at present in the Aftonian inter-Glacial period. Prof. Hershey estimates the length of the Aftonian interval at 50,000 years from the extent to which gorges were eroded during that inter-Glacial period.

While it cannot be proved that the Aftonian and Toronto formations are of the same age, the known evidence from position and fossils is favourable to that view. If the Aftonian area, covering thousands of square miles, belongs to the same inter-Glacial period, the recession of the ice began 800 miles southwest of Toronto.

Another widespread tract of inter-Glacial deposits lies 350 or 400 miles north of Toronto, along river valleys of the James Bay region, with an extent from east to west of 100 miles and from north to south of 50.

It includes 27 known outcrops of inter-Glacial lignite or peat, scattered over an area of several thousand square miles.[3] Logs of wood 17 inches in diameter have been found in the beds, but unfortunately the wood was greatly flattened by the weight of ice above it, even more so than the wood from the Don valley, and Professor Penhallow, who examined it, could not certainly

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1 Science, Vol. XXXVII, 1913, p. 523.

2 Samuel Calvin, Bull. Geol. Soc. Am., Vol. XX, 1909, pp. 341-356; and V XXII, 1911, p. 207.

3 *Interglacial Periods in Canada*, Compte Rendu, Cong. Géol. Intern., Mexico, 1906; and Bur. Mines of Ont., Vol. XII, 1901, Part 1, pp. 135-197, and Vol. XX, Part 1, pp. 234-8

determine the species. The general appearance of the wood and peat is much like that from the Toronto inter-Glacial beds, and the two sets of deposits were probably formed at the same period.

Professor BAKER is convinced of the long duration of the Mattagami inter-Glacial deposits. "Not only was there deposited a considerable thickness of stratified clays and sand, but there was sufficient time for a great peaty or swampy growth, as well as for trees of large size to mature, be buried and thoroughly carbonized before the next glaciation."[1]

The lignite beds just mentioned occur within 300 miles of the Labrador ice centre. Pushing southwestward the ice would reach the first lignite beds in 300 miles, the last in about 400 miles, while Toronto would be reached by an advance of 700 or 800 miles nearly south. The retreat of the ice when the climate changed would, of course, reverse this route, the Toronto region being set free first and the James Bay slope last. If the Aftonian region was included, the retreat and advance would be lengthened to 1,100 or 1,200 miles.

It has been shown that one inter-Glacial period, the earliest in North America, probably included deposits extending from Nebraska to the northeastern part of Ontario, a distance of 800 or 900 miles, that the inter-Glacial period was very long, much longer than post-Glacial time, and that during part of the time the climate was decidedly warmer than at present. After a withdrawal of 800 miles from its southwestern limit one can hardly believe that the remaining 300 miles to the glacial centre would resist the long continued period of mild climate, particularly when it is remembered that the central area is a low plain, with no mountains on which remnants of the ice-sheet might maintain themselves as Alpine glaciers.

The conclusion is irresistible that in at least this inter-Glacial period the Labrador ice-sheet completely vanished, to return again after many thousands of years when the earlier climatic conditions were repeated.

The Labrador ice-sheet was the greatest of the Pleistocene sheets of America and probably equalled the ice-covered area of northern Europe. If it was entirely removed by the inter-Glacial change of climate there seems no reason why any other ice-sheet should not disappear under similar conditions. Evidence of at least one great inter-Glacial interval has been found in many other regions, including tropical mountains and parts of the southern hemisphere; so that the climatic change which was powerful enough to remove the largest American ice-sheet seems to have affected all parts of the world to an important degree. One inter-Glacial period seems to have been world wide, implying causes of a general character.

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[1] *Interglacial Periods in Canada* p. 237.

RECENT DATE OF THE ATTENUATED GLACIAL BORDER IN PENNSYLVANIA.

BY

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In 1881 Professor H. CARVILL-LEWIS and myself were appointed by Professor LESLIE to mark the Glacial boundary across Pennsylvania. The results of our work are to be found in Volume Z of the Second Geological Survey of that State, and on the accompanying map. We set out with the theory that the Glacial boundary was marked by a distinct terminal moraine, but we soon perceived that in places the glacial ice had extended some distance beyond our terminal moraine. This we denominated the "fringe," but as others preferred "attenuated border," I am willing now so to denominate it. Subsequently Professor E. H. WILLIAMS, of Lehigh University, delimited the boundary of the attenuated border as shown on the map and collected a great mass of important facts bearing upon its age.

It has been generally supposed that our moraine marked the boundary of the area in this region which was covered by the so-called Wisconsin stage of advancement, and that the attenuated border corresponded to the Kansan stage in the west; also that an immense period had elapsed between the depositions on the attenuated border and those over the region to the north of our moraine. At first Professor CHAMBERLIN insisted[1] that the entire rock erosion of the rivers had intervened between these deposits. This would imply an enormous Interglacial period; for the rock erosion of the Allegheny river, extending for hundreds of miles, amounts to fully 300 feet in depth, and corresponding rocky gorges exist in the Susquehanna, Lehigh, and Delaware rivers. This supposition, however, was in due time disproved by the discovery at Warren and in its vicinity of buried channels filled with the oldest débris, and of a gravel terrace extending continuously from the present bed of the river to the top of the bordering rock shelf about 300 feet high. At Bethlehem, just above Easton, it was also found that a deeply eroded rock gorge was filled with the oldest glacial débris.[2]

Furthermore, from the examination of the deposits themselves, Professor WILLIAMS has collected abundant of data to show that the interval between these deposits is comparatively short,—in fact that no hard and fast line can be drawn between the deposits north of our line and south of it.

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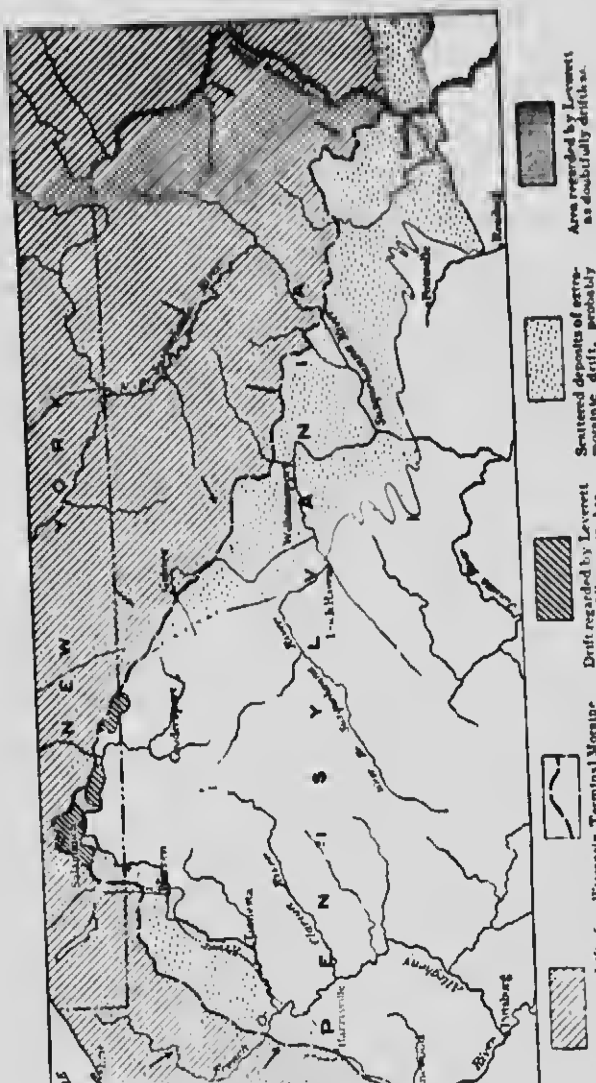
[1] U.S.G.S. Bull. 58, pp. 30, 35; also Proc. Geol. Soc. America, Vol. I, pp. 472, 473.
[2] G. F. WRIGHT, *"Ice Age in North America,"*.5th ed., pp. 131-166.



Map showing distribution of glacial deposits of Pennsylvania and adjoining portion of New York. Arrows indicate direction of glacial striæ. Scale, 1 inch = approximately 40 miles. Compiled by Wm. C. Alden, 1901. (From United States Geological Survey)

1. Near Pottsville, where the mammoth vein of anthracite coal outcrops in the oldest glacial region, the surface of the coal has been planed off by the ice movement so recently that there has been practically no oxidation of the surface, whereas just south of this limit the coal is oxidized and rendered useless to a depth of several feet. This would indicate that the time since

the earliest invasion of the ice is a mere trifle compared with pre-Glacial time.

2. The glacial deposits over the attenuated border, though for the most part highly oxidized as compared with those north of the moraine, contain also a small per cent. of unoxidized pebbles, and it is clear that this unoxidized material must determine the date of the whole deposit. In many cases, also, well rounded Canadian pebbles, deeply oxidized from the surface inwards, were subjected to ice action that wore off one side nearly to the core of unoxidized material, thus indicating that the oxidation of the pebbles was pre-Glacial, they being in their oxidized condition when picked up by the ice. Again, local pebbles mingled with the more highly oxidized materials from the far north show no greater signs of weathering or disintegration in the attenuated border than they do in the region north of the moraine. In the the case of Oriskany sandstone pebbles, this fact is very noticeable in passing northward from Bethlehem, near Easton, to the region north of the moraine. Again, it is occasionally found, as at Warren, that the calcite occurring in the glacial deposits in the form of shells has been leached away less in some portions of the attenuated border than in some places north of the border.

From these facts, which have been gathered in abundance by Professor WILLIAMS, it is evident that we have in the attenuated border, together with the great amount of material from the far north which had been oxidized in pre-Glacial time, a considerable amount of local material which does not show an excessive amount of oxidation, but which became mingled with the more highly oxidized material and was spread out in a common deposit. The larger percentage of unoxidized material north of the moraine follows naturally from the fact that it was collected after the first removal of the oxidized mass. One has but to pass anywhere from the glaciated to the unglaciated region to see how great was this original blanket of loose soil produced by long pre-Glacial oxidation. It is no uncommon thing to find granites and gneisses in the unglaciated region disintegrated to a depth of 100 feet; while in the glaciated region there has been no perceptible disintegration of the granitic areas which were planed and scratched by the ice.

It is significant that, according to Professor H. L. FAIRCHILD,[1] there are no indications in New York of any Interglacial deposits, so that, whatever may be true of the states in the Mississippi valley, there is no evidence in the eastern states of long Interglacial epochs. Even the oldest deposits in Pennsylvania are separated from the youngest by a comparatively short interval. The fluctuations of the ice front in the Mississippi valley were probably of comparatively short duration, for they must all come within the date assigned to the deposits over the attenuated Glacial border in Pennsylvania.

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[1] Presidential address Geol. Soc. America 1913.

THE SANGAMON INTERGLACIAL STAGE IN MINNESOTA AND WESTWARD.

BY

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Throughout the long Glacial period of growth, culmination, and decline of the North American and European ice-sheets, the climate responsible for this snowfall and ice accumulation fluctuated to such an extent that the boundaries of the continental glaciation were alternately extended and checked or drawn back. The large series of recognized extensions or invasions and alternating recessions of the ice boundaries in North America is recorded, with the names of the successive Glacial and inter-Glacial stages, in the following catalogue, which has been taken from the third volume of CHAMBERLIN and SALISBURY's text book, *Geology* (1906), and arranged in chronologic instead of stratigraphic order:

1. The sub-Aftonian, or Jerseyan, the earliest known invasion.
2. The Aftonian, the first known inter-Glacial interval.
3. The Kansan, or second invasion now recognized.
4. The Yarmouth, or Buchanan, the second inter-Glacial interval.
5. The Illinoian, the third invasion.
6. The Sangamon, the third inter-Glacial interval.
7. The Iowan, the fourth invasion.
8. The Peorian, the fourth inter-Glacial interval.
9. The earlier Wisconsin, the fifth invasion.
10. The fifth interval of deglaciation, as yet unnamed.
11. The Later Wisconsin, the sixth advance.
12. The glacio-lacustrine sub-stage.
13. The Champlain sub-stage (marine).

Following a suggestion of the late Professor SAMUEL CALVIN, the preferable name Nebraskan, was subsequently proposed by Prof. B. SHIMEK[1] for the first of these stages.

Without attempting a general description of our North American glacial and modified drift deposits and a discussion of the evidence they afford for each of the stages and sub-stages of the Ice Age enumerated in this list, this

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[1] Bull. Geol. Soc. America, Vol. XX, Dec. 24, 1909, p. 408; also Science, Jan. 14, 1910.

paper considers especially the Sangamon inter-Glacial stage, and endeavours to show, from the character of the drift series and from changes of river courses, that it was a very important interval in the Glacial history of southern Minnesota. Farther, I believe, and shall present arguments later in this paper to prove, that the desiccation interval in the history of the Quaternary lakes Bonneville and Lahontan in the Great Basin of interior drainage of the western United States, which occurred late in the history of these lakes, though anterior to the maximum rise in their relatively short final stages, coincided with the Sangamon stage. According to this view, one of the latest extensive stages of secular climatic change during the great Ice Age—attended by the drying up of lakes and far recession and readvance of the boundaries of the North American ice-sheet—followed the Kansan and Illinoian and preceded the Iowan drift deposition.

In twelve counties of southern Minnesota, wells in the glacial drift encounter inter-glacial beds containing wood, layers of peat, and occasionally shells of fresh-water and air-breathing molluscs, which layers are underlain and overlain by till, the direct deposit of an ice-sheet. These counties, described by the state geologist, Prof. N. H. WINCHELL, and the present writer in Volume I of the Final Report of the Geological and Natural History Survey of Minnesota, are, in their order from east to west, Fillmore, Mower, Freeborn, Steele, Faribault, Martin, Jackson, Cottonwood, Brown, Redwood, Lyon, and Rock counties.

Professor WINCHELL records many such wells in Mower county and adjacent parts of Fillmore county that penetrate a bed of peat carrying pieces of wood, thought to be pine and cedar. This inter-Glacial peat bed, varying from about one foot to six or eight feet in thickness, lies at 20–25 feet beneath the surface of LeRoy and Grand Meadow townships and the city of Austin. In other parts of this county it occurs at depths of 35, 45, and 50 feet. It probably is continuous with the extensive inter-Glacial forest bed of Aftonian age in northeastern Iowa, which was studied early and well reported by MCGEE. The other counties to the west have less abundant records of wells that pass through or into inter-Glacial forest and peat beds, which would indicate that there they were largely removed by the erosion of the ensuing stages of renewed glaciation.

Impressive evidence of a later prolonged inter-Glacial stage—correlated with the Sangamon stage in Illinois—having interrupted glaciation in the southern half of Minnesota, is supplied by the exceptional chains of lakes in Martin county, one of the central counties in the southernmost tier of this state. These chains of lakes are three in number and are named the East, Central, and West chains.

South creek receives the outflow from the East chain, which extends in a somewhat irregular northerly course for 12 miles from the Iowa line. This chain comprises ten lakes, varying from a half mile to two miles in length, with from a half to two-thirds as great widths. These lakes are bordered by rolling areas of till. Their shores ascend 30–40 feet, mostly by quite steep slopes. The spaces between the lakes are, in some cases, marshy and as wide as the narrower parts of the lakes, but in others, adjoining lakes are connected by contracted channels, such as might have been cut by the outflowing stream. Thus the series does not occupy depressions in any well-marked continuous valley.

The Central chain includes about 20 lakes, and extends 22 miles in an almost perfectly straight N.-S. course, from Perch lake, three miles south of Watonwan county, to Iowa lake which is crossed by the state line. This series of lakes lies three to six miles west of the East chain. Its outlets are South, Centre, Elm, and Perch creeks, all flowing eastward.

The shores and the country on both sides of the Central chain of lakes, as in the case of the East chain, consist of till, which rises to a moderately undulating expanse 30 to 40 or 50 feet above the lakes. Though forming a very distinct, straight series, these lakes do not occupy a well-defined continuous valley, for its width varies from one mile or more to less than an eighth of a mile, and it is interrupted in three places by water-divides, the lowest points in which are 10 to 15 feet above the adjoining lakes. Silver and Iowa lakes are the headwaters of South creek and have their outlet by a stream that runs nearly along the state line to the south end of the East chain. The middle part of the Central chain, reaching 12 miles from Summit lake to the Twin lakes, is tributary to Centre creek; and its portion farther north, excepting Perch lake, is within the belt drained by Elm creek.

East Chain lake, though dammed, has a depth of only 15 feet, and probably none of the lakes of that chain are much deeper. The maximum depths of some of the lakes in the Central chain are reported as follows: Iowa lake, 15 feet; Silver lake, the deepest of this series, about 50 feet; Hall's lake, 20 or 25 feet; Budd's lake, 16 feet, and Lake Sisseton, at Fairmont, 8 feet.

The West chain of lakes is less distinctly connected than the East and Central chains, from which it also differs in having the longer axes of some of its lakes transverse to the course of the chain, and in having shorter series of lakes joined with it as branches. Tuttle's lake at the south end of the chain lies on the state line, about four miles west of Iowa lake, the south end of the Central chain. Thence the West chain reaches 20 miles northwesterly, then nine miles northerly, and then northwest and west for eight miles to Mountain lake in Cottonwood county, its whole extent being 37 miles. Its successive portions from south to north are tributary to the East fork of Des Moines river, to Centre and Elm creeks, and to the South fork of Watonwan river. This West chain comprises about 25 lakes, extending through a region of moderately undulating till, the direct deposit of the ice sheet, with no noteworthy areas nor unusually thick included layers of water-deposited gravel and sand, which, indeed, is true of all this county.

The lakes of the south half of the Western series lie only 10-20 feet below the average level of the adjoining land, which rises in long, gentle slopes from their shores. Northward, in Cedar, Odin, and Mountain Lake townships, the contour is nearly like that along the East and Central chains, the lakes being bordered by bluffs of till, of moderate or often steep ascent, 30 to 40 feet high, the crests of which are at the general level of the slightly undulating drift sheet. In Mountain lake an island, which has given this name, rises with steep shores and table-like top about 40 feet above the lake, and has similar outlines to those of the surrounding bluffs and upland. Much of this lake is now filled with grass and reeds.

A series of four lakes, stretching west-northwest four miles in Lake Belt township, lies somewhat west of the direct course of this West chain, and may be regarded as a branch of it; and two miles east of this lake belt, another series of seven lakes, very plainly a branch of the West chain, diverges from it, and reaches almost due north 12 miles from Tuttle's and Alton lakes. To these seven, as a continuation of the same branch, ought perhaps to be added four other lakes, which are situated four to nine miles farther north.

It seems difficult to explain the origin of these remarkable lake basins in the drift. So far as they extend, they have the aspect of eroded valleys, such as have been commonly formed by the rivers of this region, but some of them are separated by divides of till as high as the country around. Thus they no longer form continuous channels, which must have been their original condition if they are parts of ancient watercourses. Nowhere else in the glacial drift have I found chains of lakes, bordered and occasionally divided by areas of till, without notable deposits of modified drift, and not occupying distinct valleys of former streams. Yet these series of lakes, plainly connected, converging in their course toward the south, and one of them receiving tributary branches, are related to each other as are confluent rivers. Their origin cannot be referred to the ordinary causes and conditions which produced the irregularly scattered lakes of drift-covered areas; but, excepting this arrangement of its lakes, Martin county is not distinguishable from the surrounding region of drift.

The explanation of these series of lakes which appears most probable is that they mark interglacial avenues of drainage and occupy portions of valleys that were excavated in the till after ice had long covered this region and had deposited most of the drift sheet, but before the last Glacial stage or epoch again enveloped this area beneath a lobe of the continental glacier, partially refilling these valleys, and leaving along their courses the present chains of lakes. They prove that the long, severely cold period, during which icefields reached south to northeastern Kansas, St. Louis, and southern Illinois, was succeeded by a milder inter-Glacial climate, which melted the ice from southern Minnesota and again permitted plants and animals to occupy the land.

But the surface till of northeastern Iowa and southeastern Minnesota, bearing its many large boulders and bordered by loess, and the somewhat later terminal and recessional moraines which are traced across the northern parts of the United States and in southern Canada, show that another great epoch of cold once more buried this region under ice. This, however, did not extend so far south in the Mississippi river basin as before. This latest ice accumulation was divided at its border into vast lobes, one of which was about 300 miles long and 100 miles wide, as indicated by the space inclosed by its first moraine, and probably from a tenth to a half mile thick.

This lobe lay upon the area that stretches from the head of Minnesota river southward to central Iowa, including Watonwan and Martin counties. Its width at this latitude, at the time of formation of its outermost, Altamont moraine, was from Albert Lea on the east to Worthington on the west along the southern edge of Minnesota.

In Martin county these three chains of lakes, and the principal branch of the West chain, appear to show that, between the time of greatest extent of the ice and the date of the last glaciation here, inter-Glacial rivers were carried southward in four confluent valleys to the East fork of Des Moines river. The present drainage is mostly transverse to this course and tributary to Blue Earth river; but the watershed and slopes that now turn it away from the Des Moines are so slight that, if the existing streams had channels from north to south, such as were probably eroded along the lines of these lake chains during the recession of the margin of the ice-sheet that reached to the farthest limit of the Glacial drift, they would continue to flow southward to the Des Moines. Probably all of this county, excepting perhaps its northeastern township was, during a long inter-Glacial epoch, included within the Des Moines basin, which still embraces a part of it at the southwest. The last glaciation doubtless added considerably to the drift, but did not entirely remold its topographic features; so that here even the inter-Glacial watercourses that were cut in the drift are little changed in some portions. They retain their steep bluffs and the present series of lakes. This interpretation is strongly confirmed by features of the valley of Minnesota river which seem to be explicable only by assuming similar causes.

Other evidences of this Sangamon inter-Glacial stage in Minnesota may also be cited. Somewhat the same conclusion as we derive from Martin county seems to be enforced by the section of the drift just southwest of New Ulm, in Brown county, about 40 miles north of these chains of lakes.

Again, Rushseba township in Chisago county, about 50 miles north of St. Paul and Minneapolis, contains a considerable tract, some five or six miles long and nearly as wide, which is underlain at some depth by reddish modified drift. This drift was spread by streams flowing down from the receding northeastern lobe of the ice-sheet, forming for a time a land surface which bore timber, and was subsequently overspread by an ice lobe whose current was from the northwest to the southeast and east. The overlying yellowish gray till, which spread as a continuous nearly level and nearly uniform bed only 10 to 20 feet thick over an area at least five miles in diameter, contains plentiful limestone fragments carried from the northwest. In this respect it is in remarkable contrast with the red till deposits beneath, which came from the northeast, contain no limestone and took their red tint from the shales and sandstones of Lake Superior. One well in this area encountered peat and decaying fragments of wood in a water-deposited clay beneath the gray till, and entered gravel and sand at the top of the older underlying modified drift, thus testifying that a land surface with peat and forest trees existed there previous to the very latest glaciation, which brought the yellowish gray till.

Yet farther north, at Barnesville, Clay county, on the southern part of the area occupied by glacial Lake Agassiz, about 190 miles northwest of St. Paul and Minneapolis, a well penetrates through 12 feet of till into quicksand, "containing several branches and trunks of trees, thought to be tamarack, up to eight inches in diameter, which lie across the well and which, together with the inflow of water, prevented further digging." This well is in the till area of the village of Barnesville and about 80 feet below the highest beach of Lake Agassiz, which passes from south to north about three miles east of this village.

At the time of my survey of that region, in 1888, I considered the occurrence of this interglacial bed within the area of the glacial lake as good evidence that the ice-sheet in that inter-Glacial stage was melted back at least far enough to give outflow into Hudson bay from Red River valley, thus draining off the inter-Glacial forerunner of Lake Agassiz. Subsequent studies and general reasoning, however, lead me to hold now the different view that probably the earlier inter-Glacial lake in this valley may have cut its southern outlet, at the site of Brown's valley, to a lower level than the well in Barnesville; or that the attitude of the land was then unlike what it is now, having then such an ascent from south to north that the Barnesville locality in that inter-Glacial time was above the general surface of the region at Brown's valley, into which the Warren river, outflowing from Lake Agassiz, cut its deep continuous valley. So I now think that we have, in the section of this well, only evidence of an ice retreat (that is, a departure of the outer part of the ice-sheet) northward to halfway between the south and north boundaries of Minnesota.

The duration of the Sangamon inter-Glacial stage in southern Minnesota in thousands of years has been estimated by Prof. N. H. WINCHELL[1] from his explorations and studies of the pre-Glacial, inter-Glacial, and post-Glacial valleys eroded by the Mississippi river in and near Minneapolis and St. Paul. He estimates this time at about 15,000 years. He thus regards the latest prolonged inter-Glacial stage here to have been nearly twice as long as the post-Glacial period, which he estimates at only about 8,000 years, from observations of the rate of recession of St. Anthony falls between Fort Snelling and Minneapolis. Confirmation of this estimate of post-Glacial time is supplied from similar measurements and studies of Niagara falls and gorge by GILBERT, WRIGHT, and the present writer. Through these and other computations we obtain also approximate measurements of the duration of the entire Ice Age, a theme to which we shall return near the end of this paper.

From the admirable studies of GILBERT and RUSSELL on Lakes Bonneville and Lahontan, in Utah and Nevada, and from the Quaternary history of Lake Mono, in California, it is ascertained that the somewhat moister climatic conditions that produced the remarkable enlargement of the lakes

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[1] *An Approximate Interglacial Chronometer*, Am. Geologist, Vol. X, Aug. and Nov., 1892, pp. 69-80 and 302.

in the Great Basin were attended with increased snowfall and glaciation upon the contiguous mountain ranges. The two stages of great rise of these Pleistocene lakes, separated by the intervening stage of their desiccation, when they were nearly or wholly evaporated away, are doubtless correlative on more northern and eastern parts of our continent with two divisions of the Ice Age that were marked by abundant snowfall and ice accumulation, while the interval of desiccation has its analogue eastward in an inter-Glacial stage of fluctuating retreat and readvance of the ice boundary. GILBERT writes of Lake Bonneville, as follows:[2]

"The Bonneville basin originated by distortion of the earth's crust, and came into existence long before the Bonneville epoch. Little is known of its earliest climatic and physical conditions, but it was comparatively dry for a long period immediately preceding the formation of the great lake. During this period, alluvial cones were formed about the bases of all its greater mountain ranges, and the smaller ranges were wholly or partly buried by valley deposits. The valley deposits may have been entirely alluvial, but were probably also partly lacustral, the lakes being of small extent.

"There followed two epochs of high water, with an interval during which the basin was nearly or quite empty. The first of these epochs was at least five times as long as the second. The second scored its water mark 90 feet higher than the first, and would have encroached still farther on the basin sides had it not been checked by outflow. During the epoch of outflow, the discharging current eroded the rim, and thus lowered the lake 375 feet; and after the outflow had ceased, the water fell by desiccation, with one notable interruption, to its present level in Great Salt lake. The inter-Bonneville epoch of low water was of greater duration than the time that has elapsed since the final desiccation.

"The history of the Bonneville oscillations is, moreover, closely paralleled by that of the Lahontan oscillations, and it is believed that they belong to a series of climatic changes affecting not only these two basins but the adjacent subdivisions of the Great Basin. . . .

"The moraines of three Pleistocene glaciers descend from the Wasatch mountains to the level of the Bonneville shore-line; the moraines of four glaciers descend from the Sierra Nevada to the level of the old shore-line of Mono lake; and the relations of these moraines to the shores of the lakes and the associated deposits indicate that the maximum stage of the lakes coincided closely with the epoch of maximum glaciation.

"The phenomena sustain the theory that the Pleistocene lakes of the western United States were coincident with the Pleistocene glaciers of the same district, and were produced by the same climatic changes. It follows as a corollary that the glacial history of this region was bipartite, two maxima of glaciation being separated, not by a mere variation in intensity, but by a cessation of glaciation."

When we compare the time ratios noted by GILBERT for the stages of

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[2] U.S.G.S., Mon. I, 1890, pp. 316-318.

these ancient lakes with the estimates of CHAMBERLIN and others for the stages of the Glacial period, it is evident that the very long time of the first rise and high water of the lakes is to be correlated with the Nebraskan, Kansan, and Illinoian stages of glaciation, taken together, while the separating inter-Glacial stages preceding the Sangamon stage have no recognized representation in the lacustrine records. The ensuing long stage of a warmer and dry climate, during which these Quaternary lakes may have entirely disappeared, coincided with the Sangamon inter-Glacial stage, and both the Quaternary history of the Great Basin and that of the Mississippi river in the vicinity of the Twin cities (Minneapolis and St. Paul), studied by WINCHELL, give evidence that this stage was longer than the Postglacial period from the final melting of the continental ice-sheet to the present day. In the second and higher, but relatively brief rise of the Quaternary lakes, estimated by GILBERT to have lasted no longer than a fifth part of the duration of the earlier rise, we have the western record corresponding to the Iowan and Wisconsin stages of renewed growth of the continental ice-sheet.

In 1895[1] I referred this principal late inter-Glacial stage in Minnesota to the time immediately preceding the Iowan stage of advancing glaciation. One year before, Mr. FRANK LEVERETT had first recognized the Illinoian drift sheet as newer than the Kansan drift, being divided from it by an interval which, three years afterward, he named the Yarmouth inter-Glacial stage. In the same paper, presented before the Iowa Academy of Sciences in December, 1897, he also proposed the name Sangamon inter-Glacial stage, from Sangamon county and river in Illinois, for the interval dividing the Illinoian till from the Iowan till and loess. The discrimination of these several drift sheets and divisions of the Ice Age, and the detailed description of the Illinoian drift sheet, are published by Leverett in Monograph XXXVIII, United States Geological Survey, 1899, entitled ***The Illinois Glacial Lobe***.

Coming next to the great question whether the Pleistocene ice-sheets of North America and Europe were wholly melted away and later renewed, as is argued by Professor JAMES GEIKIE and less decidedly by CHAMBERLIN, we cannot adduce sure proofs for such conclusions from the central areas of these great ice-sheets on either side of the Atlantic ocean. The interior of New England and of British America, like the central parts of Sweden and Norway, have not yet revealed a sequence of glacial deposits and intervening fossiliferous beds of somewhat temperate faunas and floras such as to give any conclusive evidences of complete departure of the ice-sheets and their subsequent renewal over nearly all of their former areas. Broadly speaking, only the peripheral parts of these two immense ice fields yield proofs of successive stages of glaciation that are separated by old land surfaces and fossil-bearing stratified beds, either of modified drift or of alluvial, lacustrine, or marine sedimentation.

Minnesota, which lies somewhat far back from our southern limits of

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[1] *Climatic Conditions shown by North American Interglacial Deposits*, Am. Geologist, Vol. XV, pp. 273-295; with a map.

maximum glaciation, has well ascertained proofs of a recession of the borders of the North American ice-sheet that was great enough to uncover the southern half of this state, and of renewed snowfall and ice accumulation until the borders of our continental ice sheet again reached southward as far as the Iowan and the Wisconsin drift. The earlier glaciation appears surely to have lasted much longer than the later Iowan and Wisconsin stages. Thus our Pleistocene ice age was much diversified and even very complex. Yet I would now more confidently ascribe all our North American drift formations to one prolonged and continuous Glacial period, with great fluctuations of the ice border, especially in the interior of the continent, than to regard our Ice Age as two-fold or three-fold, in the sense of having had its vast ice sheet wholly melted away, or even nearly so, with ensuing renewal of snow and icefields.

Geologically very rare, an ice age would scarcely be duplicated with so nearly the same limits of ice extension upon half of our continent. The same general conclusion is also, as I think, applicable to the European glaciation. Almost inconceivable geologic duration divided the Permian and Pleistocene ice ages. In this most recent and geologically short ice age, which has ended, as I believe, within the last 10,000 to 5,000 years, and at the threshold of the historic period, I cannot think that the stupendous climatic changes implied in the glaciation could permit complete repetition of these continental ice sheets in America and Europe, and extend in each case to so nearly the same maximum limits in the earlier and later parts of the Glacial period. It is better, until proofs are obtained in the central regions of the drift areas on each continent, to regard their time of glaciation as one and continuous with much areal oscillation, such as is proverbial of weather, during both the general stages of growth and departure.

While great uplifts of the continental areas which became enveloped by snow and ice were apparently the chief cause of the Glacial period, the astronomic cycles of the precession of the equinoxes, and the accompanying nutation, especially during a period of much increased eccentricity of the earth's orbit, may have produced alternating stages of growth and temporary decrease of the ice sheets. Thus the views of DANA and of CROLL may jointly supply the true theory of causation of this exceedingly complex Ice Age.

Among the last papers written by the late Prof. SAMUEL CALVIN, state geologist of Iowa, are two[1] treating of the glacial and interglacial series in Iowa, and most fully of the mammalian fauna of the Aftonian inter-Glacial stage. His estimates of the comparative ages of the older and newer drift sheets impress me strongly with a belief that the whole Glacial period was very long, as measured by thousands of years. Even after greatly discounting his conclusions, we may reasonably attribute to the Nebraskan, Aftonian, Kansan, Yarmouth, and Illinoian stages a combined duration of probably 200,000 years. This was represented in the Great Basin by the first period

[1] Bull. Geol. Soc. of America, Vol. XX (1910).

of Lakes Bonneville and Lahontan, and comprised all of the last astronomic period of exceptional eccentricity of the path of the earth in its annual course around the sun, from about 240,000 to 80,000 years ago, besides continuing perhaps through half of the ensuing time.

The Sangamon stage we may provisionally estimate to have extended from about 40,000 to 25,000 years ago, if we accept the computation of WINCHELL for its duration in southern Minnesota from his study of the changed Pleistocene and present courses of the Mississippi river in and near Minneapolis and St. Paul. This was the time of inter-Glacial desiccation of the Pleistocene lakes in Utah and Nevada.

Later advances of the ice border, up to the culmination of the Iowan stage, probably occupied about 10,000 years. Next came a depression of the continent, bringing the chief stage of loess deposition in the Missouri, Mississippi, and Ohio valleys, with wind transportation of loess to the uplands. This stage was closely followed by a slight uplifting of the land, and by the geologically rapid wane of the ice-sheet, this wane being attended with the formation of marginal moraines whenever climatic fluctuations covering a few years or a few decades caused the ice boundary to halt in its general recession, or for some time to readvance. The loess-deposition stage, the ensuing moderate uplift of this region, and the Wisconsin stages of waning glaciation and morainic accumulations, up to the complete disappearance of the last remnants of the ice sheet on its central and northern areas in Canada, may also have together occupied about 10,000 years, from about 15,000 to 5,000 years ago.

Within these stages of Iowan advance and Wisconsin recession and departure of the ice fields, together estimated at about 20,000 years, was the last and larger rise of the lakes in the Great Basin. During a geologically very short and late part of the glacial recession, glacial Lake Agassiz and the contemporary and later glacial lakes in the St. Lawrence basin had a duration probably no longer than 1,000 to 2,000 years, or perhaps even 5,000 years for the very complex history of the St. Lawrence glacial lakes.

Whether the very remarkable Don and Scarboro interglacial formations near Toronto, Canada, described by HINDE, COLEMAN, and others, are referable to the Sangamon stage, or, as I have argued,[1] to glacial fluctuations in the Wisconsin stages, remains to be determined by further observations and studies. What is known of the extent of glacial retreat in the Sangamon stage and of ensuing Iowan readvance in the upper Mississippi basin—most fully ascertained in southern Minnesota—justifies a belief that this inter-Glacial stage had some expression farther east toward the Atlantic coast. Evidence of it should be sought around all the boundaries of our continental glaciation.

In several former papers treating of the causes of the Ice Age, I have attributed the snow and ice accumulation to great uplifts of the land areas, giving to them a cool and snowy climate throughout the year. From the depths to which pre-Glacial land valleys are now submerged beneath the sea

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[1] Am. Geologist, Vols. XV and XXVIII, May, 1895, and Nov., 1901.

level on the coasts of North America and Europe, it is known that the elevation of the glaciated portions of these continents was 3,000 to 5,000 feet higher than now.

The depression from the high altitude, as was remarked by DANA, would transfer the southern part of the ice-sheet from a climate resembling that of Greenland to the temperate climate of southern Canada and the northern United States. Marginal melting then would push back the boundary of the ice and thus give to its front an increased steepness of slope, whereby any slight halt or readvance due to a series of years of unusual cold and snowfall would become recorded in a marginal moraine.

The predominantly wasting ice border rose probably to an altitude of 5,000 feet within 100 miles from its edge as it was being melted by the warm Wisconsin and Champlain climate, the altitude of the land being somewhat lower than now. If the retreat of the ice sheet from the northern United States and Canada occupied, as I think, about 5,000 years, disappearing earliest from the upper Missouri and Mississippi basins, and latest from New England, the province of Quebec, and Labrador, then the extension of a warm temperate flora and fauna could well keep pace with the glacial recession, so that, as on the waning Malaspina ice-sheet of Alaska, a flora like that of the same latitude today, and concomitant temperate mammalian, avian, molluscan, and insect life, may well have thrived up to the very boundary of the ice, or perhaps, in the case of the plants, mammals, birds, and insects, even extending, as in Alaska, upon the drift-covered ice border.

In the Alps the glaciers end only a few hundred feet from productive fields and gardens of flowers. Still more like the conditions of North America and Europe during the recession of their Pleistocene ice-sheets is the vast fertile plain of India, which enjoys a tropical climate, while within a short distance along its northern side, and farther west and east for an extent of 1,500 miles, runs the almost impassable Himalayan range with valleys bearing glaciers and summits crowned by perpetual snow.

The proximity of the very cold Himalayas does not brin, frosts to the neighbouring tropical plain. In like manner, the ice sheet in the Sangamon stage, or in a late part of the Wisconsin stages, still lingering on the northern half of the Red River valley, northern Ontario, New York, and New England, probably did not cause a very frigid climate to prevail in the winters, nor nights of frost in the summers, on the windward low region of southern Minnesota and parts of the basin of the Laurentian lakes, whence the ice had recently retreated.

DISCUSSION.

J. H. **LEES** (Des Moines, U.S.A.): The period of 25,000 years, estimated by Mr. UPHAM for the interval between the close of the Sangamon Inter-Glacial stage and the present is too short to include the Iowan and Wisconsin Glacial stages, the Peorian inter-Glacial stage and the present post-Glacial stage. With regard to the proximity of vegetation to modern ice- and snow-fields, this is governed at the present time by differences of altitude while the areas covered by and adjacent to the continental ice-fields were all evidently low-lying

The period covered by the erosion of the valleys now occupied by the chain lakes of southern Minnesota embraces the Iowan and the Peorian as well as the Sangamon stage, hence it cannot be taken as an index of the duration of the Sangamon stage.

ÜBER GLAZIAL UND INTERGLAZIAL IN NORDDEUTSCHLAND.

VON

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Die Eiszeit fand in Norddeutschland ein leicht hügeliges Bodenrelief mit teilweise ziemlich tief eingeschnittenen Stromtälern vor. Wir kennen, mit Ausnahme eines kleinen Gebietes an der rheinisch-niederländischen Grenze, keine pliozänen Meeresablagerungen auf deutschem Boden. Die letzte grosse Meeresinvasion hat sich im Miocän von der Nordsee aus vollzogen und das Niederrheingebiet (bis gegen Wesel), den nordwestlichen Saum von Westfalen, das Gebirgsvorland bei Ibbenbüren und Osnabrück, das nordwestliche Hannover bis Nienburg a. d. Weser, Walsrode und Lüneburg, das Elbtal bis nahe an Wittenberge, den westlichen Teil von Mecklenburg bis gegen Rostock und das ganze Land Schleswig-Holstein, sowie das südwestliche Jütland bedeckt. Zu gleicher Zeit existierte eine mediterrane Bucht in Oberschlesien. Das jetzige Ostseegebiet war ein flaches, Skandinavien mit dem Süden verbindendes Festland, und die schwedischen Flüsse erreichten Westpreussen, Pommern und das nördliche Brandenburg. Die Entwässerung erfolgte damals wahrscheinlich südlich der Ostsee in einem nach Westen gerichteten Stromsystem, dessen Ursprünge in Schweden und Nordrussland lagen. Während des älteren Pliozäns bestand in Niederschlesien, Posen und dem südlichen Westpreussen ein grosser Binnensee, dessen räumliche Beziehungen zu den pontischen und levantinischen Schichten des europäischen Südostens noch nicht näher untersucht sind.

Am Ende des Miozäns war das Meer weit ins Nordseegebiet zurückgewichen und das Land hatte sich erhoben. Von den Rheinmündungen bis zur russischen Grenze finden wir zahlreiche Stellen, an denen das Quartär tief unter dem Meeresspiegel in Hohlformen der tertiären Landfläche hinabgreift. Obwohl nun in den grösseren Städten die geologisch wertvollen tiefen Brunnenbohrungen ziemlich dicht stehen, genügt ihre Zahl doch noch nicht zur genauen Abgrenzung dieser Hohlformen nach allen Richtungen, sodass man nicht sicher entscheiden kann, ob es sich um Erosionsformen oder tektonische Einsenkungen handelt. Es spricht aber in vielen Fällen eine grössere Wahrscheinlichkeit für Erosionsformen, so namentlich in dem sehr genau bekannten Untergrunde von Hamburg. Man darf also vermuten, dass in das emporgestiegene Tertiärland die Flüsse sich entsprechend tief eingeschnitten hatten. Diese *Hebung und Erosion* dürfte *im jüngeren Pliozän* ihr Maximum erreicht haben, denn wir finden nunmehr im Osten den grossen

Posener Binnensee trocken und die zentrale Depression dieser Gegend nordwärts ins Baltikum verlegt. Zum ersten Mal bemerken wir so in der Präglazialzeit eine Andeutung der Ostseemulde, und es ist deshalb kein Wunder, wenn die älteste Vergletscherung, die dieser Periode unmittelbar gefolgt ist, sich als ein baltischer Eisstrom erweist.

Die Punkte, an denen die *Basis des Quartärs unter den Meeresspiegel* hinabreicht, verteilen sich über sämtliche Küstenprovinzen Preussens, Mecklenburg, die Hansestädte und Oldenburg; sie setzen sich einerseits nach Niederland, andererseits nach Dänemark fort. In Ostpreussen kommen sie noch in der Nähe der östlichen Grenze vor; in Westpreussen erstrecken sie sich bis an das Thorn-Küstriner Urstromtal, in Brandenburg bis fast an die schlesische Grenze, in Hannover bis über das Allertal, im Emsgebiete bis an das ältere Gebirge. Denkt man sich das Quartär abgedeckt, so würde das Meer in der Umgebung von Nord- und Ostsee weite Flächen einnehmen, aus denen landeinwärts immer dichter gescharte Inseln herausragen würden. Die innersten Meeresbuchten würden bis nahe an das mesozoische Gebirge Mitteldeutschlands vordringen. Ihre tiefste Lage scheint die Diluvialbasis in einigen Teilen von Schleswig-Holstein und in unteren Elb- und Wesergebiet zu besitzen, so z. B. bei Hamburg etwa 250 m und bei Bremen mindestens 200 m unter dem Meeresspiegel. Im baltischen Küstengebiet hebt sie sich im ganzen gegen Osten, doch kommen noch in Königsberg Tiefen bis zu 129 m unter Meeresspiegel vor.

Um nun zu einer *Gliederung der über diesem Grunde ausgedehnten mächtigen Diluvialbildungen* Norddeutschlands zu gelangen und die Frage zu lösen, wieviel Eis- und Zwischeneiszeiten an der Ablagerung derselben mitgewirkt haben, kann man zwei Wege einschlagen. Entweder geht man vom Ursprungsgebiet der Vereisungen zur Peripherie vor und sucht an der *Oberfläche* die Grenzen der einzelnen Vorstösse, oder man prüft eine möglichst grosse Anzahl von Querschnitten durch das gesamte Quartär und sucht in ihnen nach marinen, lakustren, fluviatilen oder kontinentalen Schichten und Verwitterungszonen interglazialer Herkunft, die eine Trennung der einzelnen Moränendecken ermöglichen.

Die erste Methode hat zur Voraussetzung, dass die verschiedenen Vergletscherungen, die etwa existiert haben, nicht vollkommen kongruent gewesen sind und mit dem Alter an Intensität abgenommen haben. Die Erscheinungen rechtfertigen diese Voraussetzung in einem gewissen Masse. Es besteht kein Zweifel darüber, dass sämtliche Ausbreitungen des Inlandeises von dem alten fennoskandischen Formationsschild ausgegangen sind und weit über die deutsche Ostseeküste nach Süden und Westen übergegriffen haben. Man bemerkt zunächst, dass die jüngste Eisinvasion im inneren Kreise in höchstem Masse vom Ostseebecken abhängig war. Die Küstenländer sind erfüllt von frischen, wenig verwitterten Moränenhügeln, die in breiter Zone das Baltikum umkränzen. Nur in diesen Ländern findet man jene überaus unruhigen, seenreichen Lehmhügelgebiete, die lokal als „bucklige Welt" bezeichnet werden, und nur in ihnen auch die geschiebe- und kiesreichen *Endmoränen* im engeren Sinne, an welche sich grosse Vorsandebenen anschliessen. Sie zeugen von einem besonders lebhaften Kampf zwischen Eis und Klima, einem Kampfe der wiederum nur denkbar ist, wenn das Klima keineswegs sehr kalt und trocken, das Eis aber in lebhafter Bewegung von einem hohen und unerschöpflichen Nahrgebiete war. Hierbei sei bemerkt, dass die norddeutschen Glazialisten den Begriff "Endmoräne" gegenwärtig nicht mehr so eng fassen wie im Beginn der Spezialuntersuchungen. Man rechnet ausser den Steinwällen und Kieshügeln auch grosse Teile der sog. „Grundmoränenlandschaft" d. h. hügeligen Lehmlandschaft dazu, wenn die Verhältnisse es erweisen. Neben den langen Stirnwällen des stationären Eisrandes, die sich durch eine ganze Provinz erstrecken konnten, gibt es aber eine grosse Zahl lokaler Rückzugsmoränen und unregelmässig orientierter Ablagerungen in der Nähe der alten Schmelzstromausbrüche, die das Bild der Endmoränensysteme auf den Karten ausserordentlich komplizieren. Es ist in manchen Gegenden fast unmöglich, aus diesem Gewirr von Endmoränen die kontemporanen mit einiger Sicherheit heraus zu finden. So sind es denn mehr die grossen *Randtäler*, sog. „Urstromtäler," wie sie in neuerer Zeit besonders von KEILHACK und WAHNSCHAFFE dargestellt sind, die eine feste Ordnung in die Rekonstruktion der Eisgrenzen zu bestimmten Phasen hineinbringen, obwohl auch sie vielfach anastomosieren. Ferner sei mit Beziehung auf LEVERETTS Ausführungen in seiner vergleichenden Studie über das europäische und nordamerikanische Glazialgebiet bemerkt, dass auch in den circumbaltischen Gebieten Deutschlands Grundmoränenebenen einen bedeutenden Raum einnehmen. Im Hinterland der eigentlichen Endmoränen ausgebreitet, bezeugen sie eine Auflösung der jüngsten Eisdecke in tote Felder, welche die Ausbildung eines stetigen Entwässerungssystems teils in langen Talgräben, teils in Tunnels mit Osfüllungen ermöglichten.

Die blockreichen, steilen und kurzhügeligen Endmoränen sind ein besonderes Charakteristikum der weiteren Umgebung der Ostsee. Sie reichen in Ostpreussen bis zur russischen Grenze und noch etwas über dieselbe hinaus, in Westpreussen bis in die Nähe des Thorn-Küstriner Tales, in Brandenburg bis in die Gegend nördlich von Berlin, und hören im Westen schon vor der Niederelbe auf. Nirgends sind sie einheitlicher und klarer ausgeprägt, als im östlichen Teil der cimbrischen Halbinsel, wo sie das holsteinische Seengebiet und die schleswigsche und jütische Fördenlandschaft umkränzen. Im ganzen westlichen Teil der cimbrischen Halbinsel, in Hannover, Oldenburg, Westfalen und Niederland, in der Provinz Sachsen, Südbrandenburg und Posen gibt es keine Blockmoränen, die sich mit den grossartigen circumbaltischen vergleichen lassen; vielmehr bestehen die Endmoränen dieses tieferen Binnenlandes vorwiegend aus Sand- und Kiesanhäufungen mit zerstreuten Geschieben oder aus Aufpressungen älterer diluvialer und tertiärer Sedimente, die mehr oder weniger stark mit Geschiebesand überschüttet sind.

Diese auffällige Erscheinung findet zum grossen Teil ihre Erklärung darin, dass das von den steinigen Hochgefilden auf der Nordseite der Ostsee herabfliessende Inlandeis jenseits des Meeres keine Geschiebe mehr aufnahm, sondern auf deutschem Gebiet nur über feine tonige und sandige Boden hinweggeschritt. Je weiter es nach Süden kam, umsomehr verarmte seine Grundmoräne an groben Bestandteilen. Die skandinavischen Felsstücke wurden auf dem langen Wege grösstenteils zermalmt, und man findet sie deshalb landeinwärts in immer geringerer Durchschnittsgrösse und Zahl. Erst auf dem Felsgrund der mitteldeutschen Gebirgsränder fand das Eis frische Fracht, aber hier hatte e. an Mächtigkeit und Erosionskraft stark eingebüsst. Dennoch trifft man hier, besonders in der Nähe von festbankigen Pässen, wieder Blockmoränen in denen nun das deutsche Material vorwiegt. So beschreibt z. B. Bärtling eine Endmoräne aus Blöcken von Karbonsandstein bei Hörde in Westfalen, unfern der äussersten Eisgrenze.

Die zweite Ursache des Blockreichtums vieler circumbaltischer Endmoränen ist aber offenbar die rasche Bewegung und energische Schmelzung des Ostseegletschers. Indem grosse Eismassen in verhältnismässig kurzer Zeit zur Einschmelzung gelangten und namentlich ihre Innenmoränen von den entstehenden Wassermengen kräftig aufbereitet wurden, konnten sich stellenweise Nester und Hügel aus Blockpackung bis zu 20 m Dicke und 30–40 % Grossgeschiebeinhalt bilden.

Diese Endmoränen und die mit ihnen in genetischer Einheit verbundenen „Grundmoränenlandschaften" sind durch kurze, steile Buckel ausgezeichnet, denen nicht minder kräftig modellierte Hohlformen, Kessel, Tröge und Rinnen entsprechen. Diese Hohlformen beherbergen zahllose offene Wassertümpel, kleine Seen, Sümpfe und Moore, und das Entwässerungssystem ist noch wenig durchgebildet. Je weiter man sich aber von ihnen in der Richtung zur Peripherie des norddeutschen Glazialgebietes entfernt, um so einfacher und ruhiger werden die Formen der Höhenzüge und der Geländemulden. Die Moränenhügel, die ausserhalb der grossen Vorsandebenen im westlichen Jütland, Schleswig und Holstein, in Nordhannover jenseits der Elbe und in der südlichen Mark auftauchen, haben ein ganz anderes Aussehen als die eben beschriebenen. Sie sind breiter und mächtiger gewölbt, im allgemeinen weniger steil, und sind von einem vollendet organisierten Entwässerungsnetz durchzogen. Die ursprünglichen Täler und Gründe sind verflacht, ihr Gefälle ist ausgeglichen; oft aber sind die erhabensten Massive durch ein sekundäres Schluchtensystem tief zerschlitzt, das in der strengen Gesetzmässigkeit seiner Erosionsformen zu den regellosen primären Hohlformen in schärfstem Gegensatz steht. Zwischen der Weser und dem Rhein, im mittleren Hannover, in Sachsen, der südlichen Mark und in Schlesien dehnen sich weite und sehr flache Glazialgebiete aus; grössere Moränenmassive sind hier nicht häufig, Seen und steilwandige Glazialtäler fehlen fast völlig. Das Land ist zunächst sandig und beherbergt ausgedehnte Inlandsdünen, und dann stellt sich über den ausgebreiteten Moränenböden ein neues Element ein, der *Löss*. Wir finden ihn vor den Weserbergen von Osnabrück ostwärts, bei Hannover und Braunschweig, südlich der Elbe von Magdeburg an, im Süden des Glogau-Baruther Urstromtales und von der Oder bis zur Weichsel unterhalb Warschau. Vom Lössbeginn bis zu den äussersten Grenzen der nordischen Diluviums sind die Oberflächenformen, soweit nicht der wachsende Einfluss des älteren Untergrundes ihnen kräftigeren Ausdruck gibt, in besonders hohem Masse geglättet. Schliesslich keilt sich die Moräendecke ohne verstärkte Randschwellen langsam aus. Endmoränen findet man fast nur dort, wo das Eis mit den sich ihm entgegenwerfenden Flüssen kämpfte. Mit dem nordischen Schutt mischen sich in diesen Gegenden grosse und ausgedehnte Massen einheimischer Flusssedimente, z. B. am Niederrhein, an der Weser und Saale.

Die Wanderung von der Ostsee zur äussersten Glazialgrenze führt den Forscher über die bereits erwähnten grossen Randtäler hinweg, die den Sommerwässern des Eises und den von Süden kommenden Flüssen als Ausweg zur See dienten. Da das natürliche Gefälle nach Norden den Gewässern verbaut war und nur eisfreie Zonen von ungefähr gleichbleibender Höhenlage zur Verfügung standen, bildeten sich vornehmlich *Randseen* (Stauseen) aus, die durch Überläufe miteinander in Verbindung traten. Erst allmählich konnte durch Erosion der Wasserpässe ein leidliches und vielfach recht unvollkommenes Längsgefälle hergestellt werden, und gewöhnlich liefen die Längstäler trocken, sobald das Eis sich in eine nördlichere Zone zurückgezogen und tiefere Landschaften freigegeben hatte. Ein normal durchgebildetes Flusstal nimmt von der Quelle bis zur Mündung proportional der Wasserführung an Breite zu. Die glazialen Randtäler aber zeigen, wie ein Blick auf WAHNSCHAFFES Karte lehrt, diese Proportion keineswegs; ihre unteren Abschnitte sind nicht bedeutender als die mittleren und oberen. Im mittleren und östlichen Norddeutschland ist die Zahl der Randtäler grösser als im Westen, wo sich der Raum zwischen Gebirge und Küste ein wenig verengt. Das grösste von ihnen, das sich aufwärts reich verästelt, indem es der Mehrzahl der übrigen als Endlauf dient, ist das Elbtal; ausser ihm hat im Nordwesten nur noch das Allertal eine geschlossene Prägung. Soweit die grossen Randtäler ihre Bogen nach Süden ziehen, gibt es keinen Löss; dieser hält sich vielmehr ausserhalb des Breslau-Magdeburg-Bremer Talzuges. Dagegen beschränken sich die circumbaltischen Blockmoränen auf die Regionen nördlich des Thorn-Eberswalde-Hamburger Urstromtales.

Wenn nun die Frage gestellt wird, ob und an welcher Stelle des Radius von der Ostsee bis zum Rande des Glazialphänomens der Reisende eine *Vergletscherungsgrenze* kreuzt, so wird man an diese zwei auffälligen Zonen denken: die Aussenseite der Jungendmoränen oder die Anfangslinie der Lösslandschaft. Dennoch messen die norddeutschen Quartärgeologen keiner von beiden genau diese Bedeutung bei.

Was nämlich zunächst das Kriterium der *Oberflächenformen* und ihres *Verwitterungszustandes* anbetrifft, so ist der Übergang von einem Landschaftstypus zum anderen nicht überall und nicht in jeder Hinsicht scharf. Die circumbaltischen Endmoränen zeichnen sich allerdings durch besondere Frische der Erhaltung aus. Aber schon KEILHACK hat (in Hinterpommern) grosse Unterschiede des Verwitterungsgrades in einer und derselben Glaziallandschaft nachgewiesen. Die Geschiebesande der jüngsten Moränenlandschaft sind, je nach Kombination der Faktoren (Klima, Höhenlage, Grundwasser, Vegetation) nicht selten ziemlich tief und intensiv verwittert, derart, dass alle Kalkgeschiebe fehlen und feldspathaltige Gesteine, z. B. Granit, zu Grus zerfallen sind. Beispiele dafür habe ich sowohl in der Nähe der schleswigschen wie der westpreussischen Ostseeküste beobachtet. Die Geschiebemergel-Grundmoränen sind nicht selten ausserhalb der baltischen Moränen ebenso frisch, ja noch frischer erhalten wie innerhalb derselben. LEVERETT und vor ihm bereits v. LINSTOW und andere Autoren haben auf diese Erscheinung an einigen mitteldeutschen Örtlichkeiten hingewiesen. Auf der cimbrischen Halbinsel findet man bei Schulau und Wedel unterhalb Hamburg sowie bei Bredstedt und Tondern Geschiebemergel mit äusserst geringer Entkalkungstiefe, die sich nur wenig von denjenigen Ostholsteins oder Alsens unterscheiden, obwohl sie um ein langes Stadium, wenn nicht um eine ganze Eiszeit älter sind. Selbstverständlich kann diese Erscheinung nicht die Regel sein, aber der Verwitterungszustand allein lässt sich keineswegs als sicheres Kennzeichen inkongruenter Moränendecken verwenden. Auch die Lagerung von frischem Geschiebemergel auf entkalktem Sand beweist nicht immer ein wesentlich höheres Alter des letzteren. Ich habe im westlichen Schleswig-Holstein öfters beobachtet, dass in solchen Fällen der Sand erst nach Ablagerung der Geschiebemergeldecke infolge der Grundwasser- und Grundluftbewegungen entkalkt ist, und dass diese Entkalkung sowie eine gewisse Ferrettisierung auch die Basis des Geschiebemergels bis etwa 0·5 m Höhe ergriffen hat. Häufig haben innerhalb des Sandes feinkörnige und feinporige Schichten ihren Kalkgehalt bewahrt, während die gröberen ausgelaugt sind. Dies ist im oberen Glazialdiluvium von Hamburg durch zahlreiche Bohrungen konstatiert. Wenn man annehmen wollte, dass das gesamte Glazialdiluvium von einer einzigen Vergletscherung herrührte, die stufenweise von den Aussengrenzen gegen ihr Ursprungsgebiet zurückgewichen wäre, so würden sowohl die Verwitterungserscheinungen des Ober- und flacheren Untergrundes wie der mehr oder minder frische Zustand der Oberflächenformen damit in Einklang befunden werden können. Auf grosse Entfernung sind die Unterschiede bedeutend, auf kleine wenig auffällig. Am weitesten scheint die Verwitterung in den Moränenflächen Schlesiens und Westfalens und in den höchsten Flussterrassen des Rheinlandes (z. B. der Ruhr) und des Wesergebietes vorgeschritten zu sein.

Was den Löss betrifft, so ist er ohne Frage eiszeitlichen Ursprungs und bezeichnet sogar ein Maximum des Glazialklimas. Wenn auch seine nördliche Verbreitungsgrenze ziemlich scharf ist, so fehlt es doch nicht ganz an Übergängen. Dazu gehören einerseits die lössähnlichen Feinsande der nördlichen Lüneburger Heide und des Flämings, andererseits die zerstreuten Anfänge von Lössbildungen im südlichen Oldenburg und südöstlichen Niederland. Es ist nicht notwendig anzunehmen, dass der oberflächliche Löss—vom älteren Löss sehe ich hier ab—sich nur während des Maximums einer Vereisung und nicht auch noch während der frühesten Rückzugsphasen derselben gebildet haben kann. Wenn aber letzteres der Fall gewesen ist, so fallen Löss- und Gletschergrenze nicht zusammen, sondern der Löss deckt einen Teil der Hinterlassenschaft des Gletschers. Auch ist der feine Lösstaub erst in einer gewissen Entfernung von seinen jeweiligen Ursprungsgebieten niedergefallen, nämlich dort, wohin ihn die Eiswinde trugen und wo ein bestimmter, offenbar lokal scharf umgrenzter Vegetationstypus ihn festlegte. Da er ferner ein äolisches Aufbereitungsprodukt ist, muss er in seinen Ursprungsgebieten gleichaltrige gröbere äolische Sedimente zurückgelassen haben. Als solche sehe ich die ausgedehnten Gefilde von Binnendünen in Norddeutschland an, die von Niederland bis zur russischen Grenze die Räume zwischen den circumbaltischen Moränenstaffeln und der Lössgrenze durchschwärmen, besonders die weiten Randtäler und deren Nachbarschaft.

Die Aussenseite des norddeutschen Diluviums bietet also keine hinlänglich sicheren Merkmale einer Zonengliederung, die verschieden weit landeinwärts geschrittenen Vergletscherungen entspräche. Sie kann ebensogut mit einer einmaligen, staffelförmig zurückgewichenen wie mit einer mehrfach fundamental erneuerten Vergletscherung in Einklang gebracht werden.

Die Annahme mehrerer getrennter Vergletscherungen beruht auch heute noch in erster Linie auf dem Vorkommen der *Interglazialablagerungen in verschiedenen Stufen und Zonen*, und selbst die äussere Begrenzung der Vergletscherungen wird mehr hiernach als nach morphologischen Elementen bestimmt. *Drei Vergletscherungen kommen in Frage.*

Am wenigstens ist die tief vergrabene *erste* erforscht. In Westdeutschland hat sie nicht den vollen Raum der zweiten eingenommen. Man rechnet zu ihr die am Grunde der tiefen tertiären Hohlformen unter Hamburg[1] liegenden Glazialbildungen, welche vorwiegend aus Kies und Lokalmoränen mit baltischem und vereinzeltem norwegischen Gesteinsmaterial bestehen; ferner gleichartige Geröllkiese unter Bremen, sowie unter Aurich und Papenburg in Ostfriesland. Vermutlich gehört ihr auch das ältere "Granddiluvium" von Niederland an. Welche der altdiluvialen Schotterstufen des deutschen Niederrheingebietes ihr entsprechen könnte, ob die Schotter im Liegenden der "Tegelenstufe"—FLIEGELS älteste Diluvialschotter—oder die Hauptterrassenschotter, erscheint mir noch recht unklar. Etwas weiter im Osten soll die älteste Vergletscherung der zweiten kaum nachgestanden haben. GRUPE glaubt sie im Weser-, Leine- und Vorharzgebiet weit vorgedrungen zu sehen, SIEGERT und WEISSERMEL beschreiben sie aus der Saalegegend, TIETZE ist geneigt, ihr gewisse Ablagerungen in Schlesien zuzuweisen. Im Berliner Untergrund hat sie schöne und mächtige Grundmoränen unter dem altinterglazialen Paludinenlager hinterlassen; in West- und Ostpreussen findet man sie in demselben Verhältnis. Merkwürdig ist der frische Erhaltungszustand der ältesten Grundmoränen unter dem Berliner Paludinenlager. Von Anbeginn unter dem Grundwasserspiegel gelegen, sind sie niemals ferrettisiert und zeigen deutlich, wie sehr die älteren quartären Verwitterungszonen von lokalen Bedingungen abhängen.

Zur *ersten*, offenbar langen *Interglazialzeit* gehört eine grosse Anzahl

[1] Dem ältesten Glazial haftet viel Problematisches an. Es ist z. B. schwer zu erklären, warum es die Tertiärtäler so wenig eingeebnet hat. Dieselben sind unter Hamburg mit äussert steilen und scharfen Böschungen erhalten und tragen nur auf ihrer Sohle eine schwache Moränendecke, darüber feinen Sand und Ton. Erst die zweite Grundmoräne hat sie samt dem Plateau völlig eingedeckt.

von Ablagerungen in Nord- und Mitteldeutschland. Die Nordsee scheint in einem frühen Stadium bereits der ältesten Vergletscherung entgegengewirkt zu haben. In den sinkenden Gebieten von Niederland bis zur Niederelbe lagerten sich fluvioglaziale oder Beckensedimente in Gestalt mächtiger Feinsand- und Tonschichten ab, die sehr quarzreich und kalkarm sind und, sofern sie Derivate des weichenden ältesten Eises darstellen, beweisen, dass dieses dort wenig mächtig und nicht im Stande gewesen ist, dem aufgenommenen einheimischen Material ansehnliche Mengen nordischer Gesteinstrümmer beizumengen. Endlich griff die Nordsee weit ins Landgebiet ein und schwemmte über diese Schichten im Niederelbgebiet ihre muschelreichen Sand- und Schlickabsätze. Die Fauna dieser marinen Sedimente ist teils subarktisch und boreal, teils vollkommen gemässigt, und es ist wahrscheinlich, dass die letztgenannte die jüngere ist. Mit den Flachseesedimenten wechsellagern die alten Torfe von Ütersen, Prisdorf, Hummelsbüttel, Flottbeek, Lauenburg und anderen Orten der Umgegend von Hamburg. Es ist wahrscheinlich, dass auch die marinen Diluvialbildungen des östlichen Schleswig, von Rügen, West- und Ostpreussen und Posen dieser altinterglazialen Meerestransgression angehören. Die Fauna all dieser und der niederelbischen Vorkommen enthält trotz naher Verwandtschaft keine der spezifisch jungpliozänen Formen des Amsteliens von Niederland oder der jüngsten Cragschichten von Norfolk. Hingegen ist in ihr der von NORDMANN in Dänemark zuerst erkannte *Tapes aureus* var. *eemiensis* weit verbreitet. In Westpreussen lässt sich die Gleichaltrigkeit des marinen Diluviums mit dem *Paludina diluviana*-Lager nachweisen, das in zahlreichen Bohrungen von der Altmark bis nach Ostpreussen angetroffen ist. Dem Paludinenlager entspricht im Gebiet der Saale und Unstrut in Thüringen der *Corbicula fluminalis*-Schotter. Es ist von Interesse, dass man zu Obornik in der Provinz Posen auf sekundärer Lagerstätte im jüngsten Glazialkies sowohl Conchylien des marinen Diluviums (*Cardium edule*) wie *Corbicula fluminalis* und *Paludina diluviana* in Gesellschaft von tertiären Conchylien gefunden hat.

Von der *zweiten (mittleren) Vergletscherung* wird angenommen, dass sie allein das gesamte norddeutsche Glazialgebiet vollkommen ausgefüllt hat, vom Westufer des Niederrheins bis zu den Sudeten. Nach meiner Ansicht müssen ihr am Niederrhein die Hauptterrassenschotter äquivalent sein; vielleicht korrespondiert die dortige Mittelterrasse mit einem etwas späteren Stadium. Ferner gehört der ältere Löss am Niederrhein zur Gefolgschaft der zweiten Vergletscherung.

Vornehmlich ausserhalb der circumbaltischen Blockmoränen gibt es nun zahlreiche limnische Ablagerungen, die faunistisch und floristisch von den sicheren Postglazialbildungen abweichen und sowohl deshalb wie wegen ihrer Lagerungsverhältnisse als ein jüngeres, *zweites Interglazial* angesehen werden. Faunistisch sind sie gekennzeichnet durch grosse diluviale Säugetiere wie Mammut, Wollnashorn und Riesenhirsch, sowie durch einige Binnenmollusken wie *Paludina Duboisii* und gewisse *Belgrandia*-Arten floristisch nehmen sie eine Sonderstellung ein durch die Führung von *Picea excelsa* in jetzigen Föhrengebieten sowie von *Brasenia purpurea* und *Dul-*

chium spathaceum. Die Flora ist vollkommen gemässigt und unterscheidet sich scharf von den in Schmelzwasserbecken der Endmoränenlandschaft eingeschwemmten Dryas-Floren und deutlich auch von den etwas mehr temperierten Floren der spätglazialen Alleröd-Schwankung und der ostpreussischen Interstadial-bildungen.

Dennoch ist die Frage offen, ob alle diese "jüngeren Interglazialbildungen" zusammengehören. Im südlichen Jütland (Brörup), am Kaiser-Wilhelms-Kanal (Beldorf, Bornholt) und bei Schulau, Ohlsdorf, Winterhude, Steinbek und Lauenburg in der Hamburger Gegend liegen über den fraglichen Torfschichten lediglich Sande oder Kiese, niemals echte Grundmoränen. In einigen Fällen, z. B. bei Schulau, enthalten die Sande viele Steine bis zu Kopfgrösse, aber keine Grossgeschiebe; an andern Orten, z. B. bei Beldorf, Bornholt und Winterhude, enthalten sie nur Kies und feines Geröll. Ist es demgemäss schon fraglich, ob sie überhaupt von einem Gletscher überschritten sind, so ist est vollends undenkbar, dass dieser Gletscher mächtig und ausgedehnt genug gewesen sei, um die Elbe zu überschreiten und das 100 Meter hohe Plateau der Lüneburger Heide bis in die Nähe des Aller-Weser-Talzuges zu bedecken. Nun kommen aber in der Lüneburger Heide bedeutende Sedimente von Süsswasserseen (Kalk, Kieselguhr) vor, die zwar ebenfalls keine typische Grundmoränendecke, aber doch mächtigere Geschiebesande mit grösseren Blöcken tragen. Während an den südholsteinischen Torfen nur geringe Lagerungsstörungen zu beobachten sind, die durch das Gewicht der Decksande hervorgebracht sein können, zeigen sich an den Kieselguhrlagern Stauchungen von grösserem Ausmass und glazialem Habitus. Ich kann mir deshalb nicht vorstellen, dass diese mit jenen gleichzeitig entstanden sind und habe den Eindruck, dass die nördlichen und die südlichen "Interglazialschichten" verschiedenen Schwankungen angehören. Merkwürdig sind die marinen Schichten, die im Eidergebiet östlich von Beldorf unter denselben Lagerungsformen auftreten, wie der "Interglazialtorf." Man hat im Kaiser-Wilhelm-Kanal etwa 9 m unter der Landoberfläche marine Schichten gefunden, die von ziemlich mächtigem geschichteten Sand und darüber einem rezenten Torfmoor bedeckt sind, ihrerseits aber auf Kies und Geschiebemergel lagern. Es fehlt ihnen eine Moränenbedeckung, und ZEISE erklärte sie deshalb als altalluviale Ablagerungen im Innenwinkel einer tief landeinwärts greifenden "Eiderförde". Später machte NORDMANN darauf aufmerksam, dass ihre Fauna derjenigen der "Eemschichten" von Niederland entspricht und dieselbe auffallend grosse var. *eemiensis* des *Tapes aureus* enthält, die man in den marinen Diluvialbildungen von Schleswig, den südwestlichen dänischen Inseln und Westpreussen findet. Diese Varietät war bisher in sicheren Postglazialablagerungen des Nord- und Ostseegebietes nicht gefunden. Neuerdings aber hat H. SCHÜTTE in Oldenburg dieselbe in Baggersanden aus der Nähe der Insel Wangerooge vor der Oldenburgischen Küste entdeckt, und zwar findet man sie dortselbst vollkommen im Bereich des tieferen Alluviums. Es liegt somit kein Grund mehr vor, sie [illegible] ausschliesslich diluvial zu erklären. Ich muss auch bekennen, dass mir die Lagerungsverhältnisse der

Eemformation in der „Geldersehen Vallei" und anderen Gebieten an der Südersee durchaus nicht unbedingt beweiskräftig für ein diluviales Alter derselben erscheinen. Ein Hauptargument für letzteres war die Erklärung der die Eemformation bedeckenden rheinischen Niederterrasse als Äquivalent der jüngsten Vereisung Norddeutschlands. Allein welches sind die Beweise für diese Erklärung? WUNSTORF hat neuerdings in seiner Arbeit über den niederrheinischen "Schotterlehm" das chronologische Dilemma definiert, in welches der Stratigraph gerät, wenn er die Niederterrasse nicht als postglaziale sondern jungglaziale Talstufe rechnet.

In der südlichen Umgebung von Berlin kommen bei Motzen und Phöben ähnliche Torflager wie die eben behandelten vor, welche Skelette des Riesenhirsches enthalten und von Konchyllagern mit *Paludina Duboisi* begleitet werden. Diese Torflager werden jedoch von echtem Geschiebelehm, wenn auch in geringer Mächtigkeit, bedeckt. Sie haben also tatsächlich einen schwachen Eisvorstoss über sich ergehen lassen. Indessen glaube ich kaum, dass dies derselbe Eisvorstoss gewesen sein kann, der seitwärts bis Halle vorgedrungen sein soll. Bei Phöben, unfern Potsdam, liegt der junge Interglazialtorf in einer weiten, von Staumoränen umgebenen Ebene, die gegenwärtig noch fast ebenso aussieht wie zur Interglazialzeit. Überhaupt waren die grossen Talflächen bezw. Becken der südlichen Umgebung von Berlin nicht allein zur Spät- und Postglazialzeit, sondern wahrscheinlich schon in einem etwas früheren Stadium, der sog. jüngeren Interglazialzeit, vorhanden. Ja, es ist merkwürdig, dass auch in der durch die mächtige Hauptvereisung von diesen Perioden geschiedenen älteren Interglazialzeit an derselben Stelle grosse Niederungen mit Flüssen und Seen bestanden haben, in welchen sich das *Paludina diluviana*-Lager entwickelte. Nirgends in Norddeutschland haben wir deshalb ein so vollkommenes Diluvialprofil wie hier. Die Bohrungen bei Phöben zeigen uns in der Tat in einem und demselben Bohrloch zwei stratigraphisch und faunistisch verschiedene Interglazialhorizonte, den unteren der *Paludina diluviana* und den oberen der P. Duboisii. Diese wertvolle Festsellung ist das Verdienst von MENZEL und SOENDEROP.

Es ist nicht meine Absicht, in diesem kurzen stratigraphischen Überblick alle Äquivalente der beiden Berliner Interglazialhorizonte aufzuzählen. Diese Aufgabe ist ausserdem sehr kompliziert und führt zu wenig sicheren, kritisch antastbaren Resultaten. Man hat versucht den Horizont von Rixdorf, Motzen, Phöben, Lauenburg, usw. mit stratigraphischen Mitteln nordwärts in das circumbaltische Blockmoränengebiet zu verfolgen. Man benutzte dazu Teilungen der Grundmoränen, Auslaugungszonen der Sandmittel, Grundwasserhorizonte usw., war aber stets zu weiten und gewagten Sprüngen über Gebiete genötigt, in denen diese Kennzeichen fehlen. So parallelisierte man z. B. Torflager, die bei Kiel von mächtiger Grundmoräne bedeckt sind, mit den fast freiliegenden von Beldorf, usw. Wie weit dies berechtigt ist und eine jüngste, vollkommen neue und selbständige Vergletscherung des circumbaltischen Gebietes zu beweisen vermag, sei dahingestellt. Es ist immerhin merkwürdig, dass einige Torfflöze auch innerhalb der circumbaltischen Blockmoränen kaum stärkere Bedeckung tragen wie die äusseren.

z. B. bei Veile, Flensburg, Schleswig und Greifswald, eine Bedeckung die, wenn sie wirklich glazial ist, doch im Missverhältnis zu der Mächtigkeit der vermeintlich kontemporanen Blockmoränen steht.

Es bleibt als gewiss bestehen, dass die Ablagerungen, welche zur jüngeren Interglazialperiode gerechnet werden, eine ausserordentliche Mässigung des Klimas beweisen; ob diese Mässigung nur einmal vorgekommen ist und das ganze Gebiet der Hauptvergletscherung gleichzeitig ergriffen hat, oder ob sie in Form zonarer Schwankungen sich wiederholte und dem Spätstadium der Haupteiszeit nachrückte, erscheint mir ungewiss. Ebenso ungewiss erscheint mir eine Transgression des Meeres in dieser "jüngeren Interglazialzeit"; die *Tapes*-Schichten der "Eiderförde" und vielleicht auch diejenigen der Gelderschen Vallei dürften postglazial sein und keinesfalls mit den altdiluvialen von Ostschleswig und Westpreussen zusammengehören.

Die Grenzen der *jüngsten, dritten Vereisung Norddeutschlands* werden mit mehr oder minder grosser Wahrscheinlichkeit von der Niederelbe zur Aller und in die Magdeburger Gegend gezogen. Von dort laufen sie über den Fläming, dann etwa auf Grünberg in Schlesien, Lissa und Jarotschin in Posen und die Weichselgegend nördlich von Warschau hinzu. Näheres über den westlichen Teil findet man bei STOLLER, über den mittleren bei MENZEL, KEILHACK, WIEGERS und Anderen, über den östlichen bei TIETZE und BEHR. E. WERTH gibt einen abweichenden, im ganzen noch weiter südwärts vorgeschobenen Verlauf an.

Jüngere Fundamentalvergletscherungen kennt man in Norddeutschland nicht, wohl aber zahlreiche Rückzugsstaffeln und Schwankungen. In der sog. "Alleröd-Oszillation" von Dänemark und Schleswig-Holstein vermag ich nur lokale, von einander verschiedene und nicht länderweit kontemporane Erscheinungen zu erkennen.

Es ist bisher nicht gelungen, sichere Verbindung zwischen den von PENCK und BRÜCKNER behaupteten vier alpinen und unseren drei norddeutschen Vergletscherungen herzustellen; der Versuch, dies dadurch zu erreichen, dass man in Norddeutschland eine Vergletscherung einschiebt, muss unter allen Umständen missglücken.

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EARLY PLEISTOCENE GLACIATION IN THE ROCKY MOUNTAINS OF GLACIER NATIONAL PARK, MONTANA.[1]

BY

WM. C. ALDEN,

United States Geological Survey, Washington.

With a map.

Glacier National Park comprises that part of the front range of the Rocky mountains in Montana lying between the line of the Great Northern railway and the International boundary. Immediately adjacent to it on the east is the Blackfeet Indian Reservation and to the north is Alberta. Investigations by the writer and Mr. J. E. THOMAS in connection with the survey of Glacier Park by the United States Geological Survey in 1911, and by the writer and Mr. EUGENE STEBINGER in connection with a geological survey of the Blackfeet Indian Reservation in 1912, showed that the so-called "quartzite gravels" which cap remnants of the Tertiary peneplain, to which Mr. BAILEY WILLIS has given the name Blackfoot peneplain, are in reality glacial drift that was deposited by an extension of the Rocky Mountain glaciers on to the plains in early Pleistocene time and prior to the dissection of this peneplain. The relations of these deposits and their modification by weathering indicate that this extension of the mountain ice occurred as early as the Kansan if not the pre-Kansan extension of the Continental ice-sheets into the northern Mississippi valley.

The relations of these high-level tracts to the mountains and to the present drainage lines are shown on the accompanying map (Pl. I) and also on the Chief Mountain, Browning, and Blackfoot sheets of the topographic map published by the U. S. Geological Survey, the contour interval being 100 feet.[2] The remnants of the early mountain drift are on either side of Belly river, on Kennedy ridge east of Chief mountain, on Swift Current and Boulder ridges to the north and south of Swift Current creek, on Hudson Bay divide and St. Mary ridge east of St. Mary river and lake, on Milk River ridge and other ridges bordering Milk river, on the ridge south of Cutbank creek and on the ridge north of Lower Two Medicine lake. The flat tops of these high-level deposits stand at elevations of 5,300 to 6,300 feet above sea-level and at heights above the present drainage lines ranging from a few hundred to 1,600 feet.

The high mountain range on the west is shown on this map by the broken-

[1] Published by permission of the Director of the United States Geological Survey.
[2] The contour interval on the Blackfoot sheet is 20 feet.

line shading, two large, composite, glacial catchment basins being differentiated. From the southern one of these Two Medicine glacier spread out broadly upon the plain (over the stippled tract) at the last, or Wisconsin stage, of glaciation, reaching a distance of nearly 40 miles from the continental divide and at one point reaching the limit of extension of the continental ice-sheet which centred in the Keewatin plateau. The area covered by the continental ice is shown by the line-shading of the north and east parts of the map. The high, flat-topped tracts carrying the early Glacial drift are shown on the map by the heavy and lighter shading. These are the remnants of the highest, or Blackfoot, peneplain and of a second, lower, plain.

The late Wisconsin age of the drift of Two Medicine glacier is indicated by the freshness of the drift and the uneroded surface of its moraines.

The deposit of early Glacial drift is exposed in a fresh scarp at the west slope of the highest part of a ridge north of Two Medicine lake. Here the evidence of long exposure to weathering is particularly well marked. The deposit consists of 150 feet of exposed glacial till composed of a reddish clayey matrix and pebbles and boulders of white, yellowish, pink, and red quartzite, maroon and green siliceous argillite, diorite, and buff and gray limestone, all derived from the mountains to the west. The pebbles and boulders range in size from small to masses six feet in length and many are beautifully striated. The limestone pebbles have been almost entirely removed by solution from the upper part of the deposit, though plentiful 15 to 20 feet below the surface. The calcium carbonate carried down by the percolating water and redeposited has cemented the drift below to a firm, hard, tillite conglomerate, which projects in ledges and towers from the steep slope. Similar tillite was observed in several of the other exposures where the high-level drift was thick. The smaller valley next north of this ridge is 1,000 to 1,200 feet deep, and contains no glacial drift.

At the last stage of glaciation, glaciers extended down Lake creek and Cutbank valleys, coalesced and reached 10 miles from the mountain front.
creek.

Fig. 1.—View looking westward to Rocky mountains across remnants of the highest or Blackfoot peneplain from a point 10 miles east of Duck lake. The valley of Middle Fork of Milk river (in middle ground) is cut 400 to 500 feet below these remnants of the high-level plain. (From photograph.)

This ice spilled through gaps in Milk River ridge to the north but barely reached the flat top of the old drift at one place 1,000 feet above the present

Fig. 1, which is drawn from a photograph, is a view looking westward a distance of 20 miles or more from a point on one of the high, flat-topped, drift-capped remnants of the Blackfoot peneplain. This shows the whole 40 miles of the mountain front of Glacier National Park, from Chief mountain on the right or north to Marias pass on the south, rising above the dissected Blackfoot peneplain. The valley of Middle Fork of Milk river in the middle ground is cut 500 feet deep in the upturned and beveled shales and sandstones that underlie this plain, although the stream does not head in the mountains and receives no drainage therefrom. In the middle background may be seen the crest of St. Mary ridge lying athwart the mountain gorge in which lies Upper St. Mary lake.

Fig. 2 is a view looking northeastward from a point on the flat top of

FIG. 2.—View northeastward from Browning-Babb stage-road on the crest of Milk River ridge showing the relations of the second peneplain, in foreground, to a remnant of the first, or Blackfoot peneplain, in background. (From photograph, partly diagrammatic in foreground.)

the main part of Milk River ridge, on a second, lower, drift-capped plain to a drift-capped remnant of the highest plain, 20 miles from the mountain front.

At the time when this early drift was deposited the ice heading in St. Mary and adjacent valleys evidently extended directly northeastward on to the Blackfoot peneplain (Pl. 1). By the time of the last great extension of the ice, so deep and broad a trough had been developed west of St. Mary ridge and the Hudson Bay divide that St. Mary glacier, instead of extending eastward on to the high-level plain, was diverted northward down St. Mary valley into southern Alberta. The St. Mary lakes now lie 1,600 feet below the crest of St. Mary ridge. The ice completely filled the valley and laid a lateral moraine upon the early drift which in places forms the upper 200-300 feet of the ridge. In the vicinity of Duck lake, where the crest is lower, the ice extended a short distance on to the upland, leaving its well-marked moraine encircling the lake basin. The ice did not, however, override the crest of Hudson Bay divide beyond a point north of Duck lake. At this point, which is 1,300 feet above St. Mary river, the moraine begins to descend the eroded north slope of the ridge. At the place shown in Fig. 3, the moraine of the later drift is 200 feet below the flat top of the divide and a few miles farther northeast it is 400 feet below the crest of the ridge. This Hudson Bay divide is capped with the so-called quartzite gravel. At some places it has the composition of glacial till; and as far eastward as traversed by the writer, where the gravels had not been removed by erosion—a distance of nearly 15 miles from the point where the later moraine crossed — striated, glacial pebbles were found in the deposit.

The old drift is exposed in the marginal scarp of the flat top of Swift Current ridge 1,100 to 1,200 feet above the present stream; in Kennedy ridge (Pl. II), the narrow remnant of the high divide five miles east of Chief mountain and 900 feet above the creek on the south; and in scarps at the top of the slope east of Belly river, 1,300 to 1,600 feet above this stream.

That a very long time intervened between the deposition of the earlier and later drift is evident from the topographic relations described. It is

FIG. 3. View looking eastward from a point about 4 miles north of Duck lake, showing relations of the terminal moraine of St. Mary glacier, of Wisconsin stage of glaciation, to the north slope of the Hudson Bay divide on whose top lies pre-Wisconsin glacial drift.

also clear from the degree of modification of the older drift by weathering. On Two Medicine ridge, as already stated, where there is a thickness of 150 feet of till, and on St. Mary ridge, where there is, in places, nearly 300 feet of early drift, the limestone pebbles and bowlders have been for the most part removed by solution from the upper 15 to 20 feet of the deposit, and the drift below has been cemented by deposition of calcium carbonate to a hard tillite conglomerate. The same is true in other places where the deposit is thick. Where it is thin no limestones are found, they having been entirely removed by solution. The diorite pebbles are in a state of disintegration and the glacial striæ have been removed by etching from almost all the pebbles, excepting only the densest fine-grained siliceous rocks, the greenish so-called argillite. Some of the latter were found 20 miles out from the mountain-front on the isolated remnant shown in Fig. 2. These are typical glaciated pebbles, some of the striæ being as sharp and fine as could be cut by an engraver's tool.

The gravel capping the isolated Horsethief and Landslide buttes, 30 to 40 miles from the mountain-front, is of the same character as that nearer the mountains, but we did not find any striated pebbles at these places.

It is evident that a very large amount of erosion of the plains has been accomplished since the deposition of this early drift. Not only has there been

FIG. 1. Mesa of "Kennedy gravel," probably pre-Wisconsin glacial drift, five miles east of Chief mountain (Photo by Bailey Willis.)

dissection of the highest plain, remnants of which are shown heavily shaded on the map (Pl. I), but there also was developed a second, lower, extensive flat plain, whose remnants, capped by similar early drift, are shown on the map by a lighter shade. In this were cut valleys several hundred feet deep with broad bottoms representing a third stage of peneplanation, and into these third plains Wisconsin and post-Wisconsin streams have cut sharp, inner valleys.

In this brief paper a full discussion of the phenomena and of the relations with the deposits in southern Alberta can not be presented. A more detailed discussion is presented in the Bulletin of the Geological Society of America, Vol. XXIV, 1913.

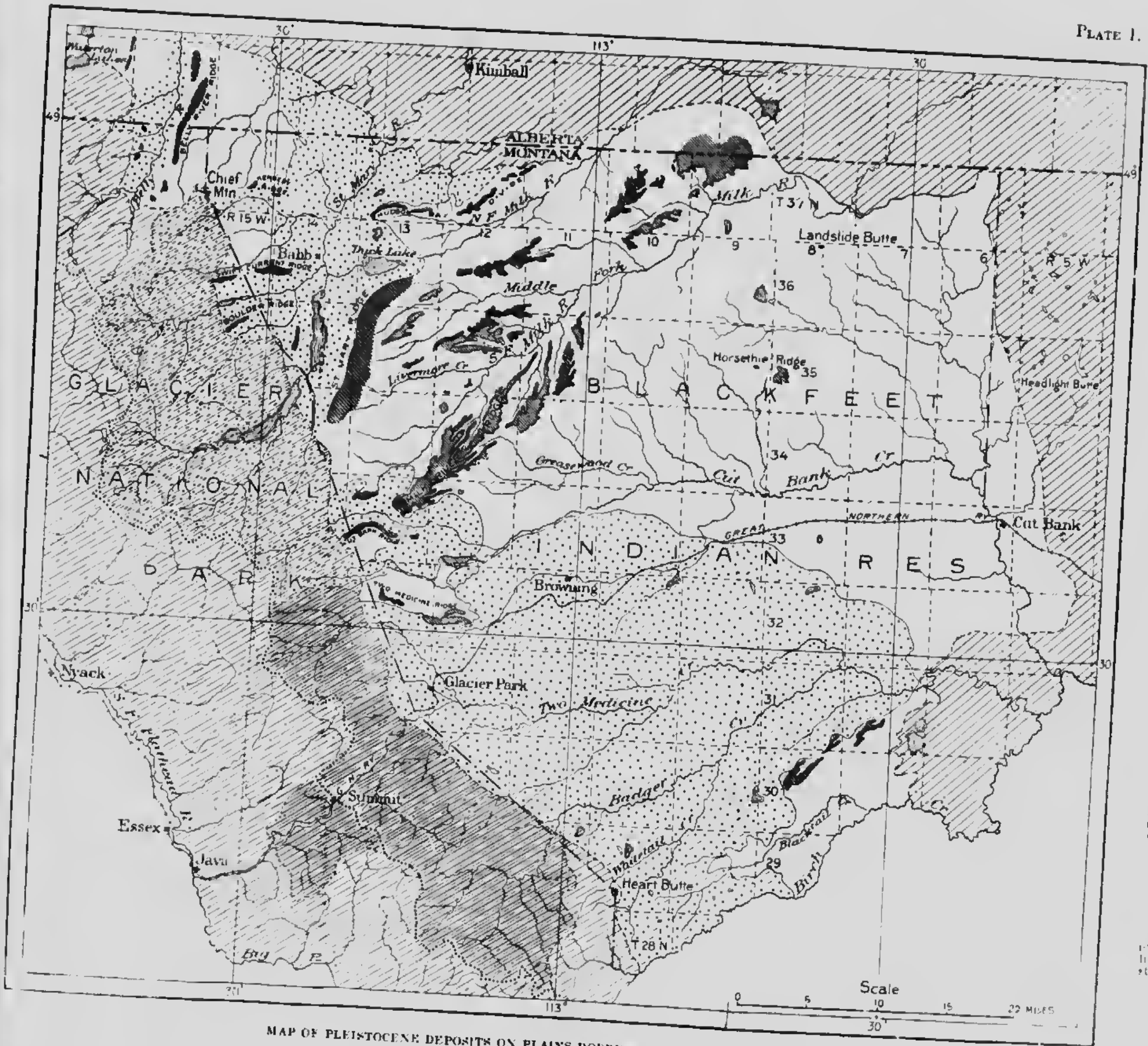
Where the streams headed in the mountains, almost all traces of the high-level plains have been removed. The mountain waters which would otherwise have been tributary to Milk river have been captured for the Hudson Bay system by St. Mary river, so that in the Milk River basin are the best preserved drift-capped remnants. Yet even here the amount of erosion has been great. North of the International boundary no such remnants are known to the writer, excepting in the vicinity of Belly river. On Oldman and Belly rivers deposits of pre-Wisconsin drift of the Keewatin ice-sheet have been found by Dawson and McConnell and also seen by the writer in places in the valley bottoms. This early continental drift is not known to be as old as the high-level drift in Montana but from the fact that this drift is down in the valleys instead of on remnants of high-level plains, it may be inferred that in the region north of the boundary more erosion had already been accomplished than in Montana, before the early glaciation occurred. It is thus possible, if not probable, that the excavation of St. Mary valley below the level of the highest plain was begun before the early mountain ice extended eastward on to this plain. A comparison of the capacity of the catchment basin of Two Medicine glacier of the last stage of glacier extension with that of the catchment basin of the ice which deposited the older mountain drift farther north shows them to be approximately equal, and inspection of the topography also seems to indicate that the ridges and valleys overridden by Two Medicine glacier were such as to offer about the same amount of retardation to the ice movement as would have been offered by St. Mary ridge when St. Mary valley was 800 to 1,000 feet less deep than it is now. Hence I think it must be conceded that St. Mary valley has been deepened at least 800-1,000 feet, and that a correspondingly large amount of sculpturing of the mountain mass has been accomplished since the early Pleistocene glaciation.

There are some indications that the drift on the second set of high-level plain remnants was deposited at a distinct stage of mountain glaciation intermediate between the glaciation of the highest or Blackfoot plain and the extension of the glaciers down on to the third set of plains at the last, or Wisconsin, stage. The evidence in regard to this, however, is not regarded as conclusive.

W. C.

W. C. ALDEN.

PLATE 1.



MAP OF PLEISTOCENE DEPOSITS ON PLAINS BORDERING THE ROCKY MOUNTAINS IN THE REGION OF GLACIER NATIONAL PARK, MONTANA,

By
Wm. C. Alden and Eugene Stebinger,
U. S. Geological Survey.
1912.

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LE COM MENCEMENT ET LA FIN DE LA PÉRIODE GLACIAIRE.

PAR

N. O. HOLST,

Retraité de la Service géologique de Suède, Stockholm, Suède.

Dr. N. O. HOLST hat dem XII Internationalen Geologenkongress eine Abhandlung "*Le commencement et la fin de la période glaciaire*" eingesandt, die in einem der nächsten Hefte von "L'Anthropologie" gedruckt werden soll[1] und deren wichtigster Inhalt kurz folgender ist:

In einer früheren Arbeit "*Der Alnarpsfluss, ein schwedischer Cromer-fluss*" hat HOLST südschwedische Flussablagerungen beschrieben, die haupt-ächlich aus einem gleichmässig feinen bernsteinführenden pliocänen Fluss-and bestehen. Der Sand enthält 80-90% Kieselsäure (im wesentlichen uarzkörner). Aus etwa hundert Tiefbohrungen hat sich mit voller Deut-chkeit ergeben, dass diese Ablagerungen recht mächtig sind und dass das lussbett somit Millionen von Kubikmetern dieses reinen Sandes enthalten uss. *Derselbe ist vollkommen steinfrei.* Unmöglich könnte dies der Fall sein, enn der Fluss eine moränenbedeckte Landschaft durchströmt hätte. Wenn mit in Südschweden keine Spur einer Vergletscherung gefunden ist, die älter re als der Alnarpsfluss, eine ältere Eiszeit also nicht dagewesen ist, so kann e solche noch viel weniger in weiter südlich gelegenen Gebieten aufge-ten sein. *Der Alnarpsfluss räumt also endgültig mit allen älteren oder ocänen Eiszeiten auf.*

Der gewaltige Alnarpsfluss, der auch hinsichtlich seiner Grösse sehr wohl en Vergleich mit dem Cromerfluss (dem vorzeitlichen Rhein) erlaubt, ist Süden gekommen und muss das Bernsteinland Ostpreussen berührt en, wie der Bernsteingehalt des Flussandes beweist. Er hat aber auch lüsse von Norden gehabt, wie einige nordische Pflanzenreste (*Salix polaris*) beweisen. Das Inlandeis war bereits im Anrücken begriffen und scheint inem etwas späteren Stadium dem Fluss ein jähes Ende bereitet zu haben. hat also hier eine *sehr scharfe Grenze zwischen den pliocänen*, präglazialen, *den quartären*, glazialen, Ablagerungen, welche letztere die ersteren in hnlicher Mächtigkeit überlagern.

Die fossile Flora im Flussbett hat zwar sekundär auch einige ältere, ter-Arten aufzuweisen, ist aber im ganzen dieselbe wie diejenige des Forest-, weshalb die Ablagerungen des Alnarpsflusses zum Pliocän gezogen en müssen, sofern man diejenigen des Cromerflusses dorthin rechnet.

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[1] Nachher in L'Anthropologie, Tome XXIV, 1913, Nos. 4-5, gedruckt.

Vorstehendes hat HOLST bereits in seinem Aufsatz "*Der Alnarpsfluss*" auseinandergesetzt. In seiner neuesten, jetzt vorliegenden Abhandlung geht er in derselben Richtung weiter.

Die Ablagerungen des Alnarpsflusses sowohl wie des Cromerflusses gehören dem Horizonte an, der durch die Muschel *Corbicula fluminalis* und deren wärmeliebende Begleitmollusken charakterisiert wird. Es werden Beweise dafür beigebracht, dass dieser Horizont in England, Belgien und Norddeutschland (Thüringen) als pliocän, bezw. durchaus präglazial angesehen werden muss.

Der *Corbicula*-Horizont ist aber ungefähr der gleiche wie der *Hippopotamus*-Horizont, und damit gleichaltrig ist auch die "*ältere* diluviale Fauna" mit *Machairodus, Trogontherium, Ursus spelaeus, Elephas antiquus, Rhinoceros Merckii, Cervus euryceros* und andern Säugetierarten. Diese Fauna wird also gleichfalls pliocän und präglazial.

Ein ganz anderes Gepräge hat dagegen die Fauna der Glazialperiode, und sie ist deutlich charakterisiert durch das Auftreten der hochnordischen Tiere in Mitteleuropa. Charakteristische Tiere für die Eiszeit sind unter den Fischen der Lachs und die Lagopus-Arten unter den Vögeln. Grösseren Wert für die Feststellung der Grenzen der Eiszeit hat jedoch die zugehörige Säugetierfauna, die besser bekannt ist. Charakteristische Arten sind: *Ovibos moschatus, Elephas primigenius, Rhinoceros tichorhinus, Cervus tarandus, Myodes lemmus, M. torquatus, Canis lagopus* und *Gulo borealis*. Solange als diese hochnordischen Arten in südlicheren Gegenden ausserhalb ihrer eigentlichen nördlichen Heimat auftreten, dauert die Eiszeit an, aber nicht länger.

Wendet man diese geologischen Resultate auf die Archaeologie an, so ergiebt sich, dass das Chelléen präglazial wird, das Acheuléen und der Beginn des Moustériens der Übergangszeit zur Glazialperiode angehört, während der spätere Abschnitt des Moustériens in den Höhepunkt der Eiszeit fällt. Die Eiszeit dauert sodann während des ganzen Paläolithicums bis zum Schluss des Magdaléniens an. Während der Mitte der Eiszeit, bezw. während des Aurignaciens und Solutréens vollzog sich indessen die grosse baltische Oscillation[1] des Inlandeises, die während des Magdaléniens durch einen geringeren Vorstoss des Eises bis zum baltischen Höhenrücken abgeschlossen wurde.

HOLST, welcher sich JAMIESONS Ansicht über die Fähigkeit des Inlandeises, durch seinen Druck Landoscillationen hervorzurufen, anschliesst, erklärt, dass die Entstehung der Eiszeit auf tertiären Landhebungen beruht und ihre Beendigung auf den vom Eise selbst verursachten Landsenkungen. Man kann also sagen, dass die Eizeit ihre eigene Existenz vernichtet hat.

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[1] In Anbetracht der grossen Übereinstimmung zwischen dem allgemeinen Verlauf der Eiszeit in Europa und Nordamerika muss die grosse baltische Oszillation ihr deutliches Gegenstück auf dem letzteren Kontinent gehabt haben. Sollte dies etwas anderes gewesen sein als diegenige, von der HINDE-COLEMANS schönes Profil bei Toronto Zeugnis ablegt? Eine nicht ferne Zukunft wird sicherlich eine endgültige Antwort auf diese Frage bringen. (Zusatz während des Druckes, von N. O. HOLST.)

Aber eben deshalb kann die Eiszeit nicht von so langer Dauer gewesen sein, wie man gewöhnlich vermutet. Ihr Beginn, und damit zugleich der Beginn des etwas weiter zurückliegenden Paläolithicums muss unserer Zeit näher gerückt werden, als das bisher geschehen ist. Dafür sprechen: 1) die geringe Zahl der fossilen Menschenreste aus der paläolithischen Zeit; 2) die geringe Mächtigkeit der paläolithischen Schichten; und 3) die unbedeutende Variation der Fauna und Flora nach Beginn der Eiszeit. Während Penck den Beginn der paläolithischen Zeit 200,000 Jahre zurückverlegt, begnügt sich Holst mit 30,000 Jahren als Maximum für den gleichen Zeitraum.

Auch der Mensch hat in dieser Zeit wenig variiert. Die Entwicklung, die in den verschiedenen paläolithischen Rassen gipfelte, liegt nämlich jenseits des Paläolithicums. Die niedrigst stehende dieser Rassen, der Neandertaler, mit seinen pithecoiden Charakterzügen ist ein aussterbendes Relikt, der so zurückgeblieben gewesen zu sein scheint, dass es öfters zweifelhaft gewesen ist, ob er irgendwie in der Lage war, sein Blut mit den Vorfahren der heute lebenden Menschen zu mischen.

Die Urbildung des Menschen liegt weit jenseits des Paläolithicums und kann deshalb nicht in Europa vor sich gegangen sein. Es ist wahrscheinlich, dass sie in der Heimat der anthropoiden Affen erfolgte, auf den Sundainseln oder in Äquatorialafrika, wo Orang Utang, Gorilla und Schimpanse zu Hause sind.

Zwischen dieser Urbildung und dem ersten Auftreten des Menschen in Europa liegt ein weiter und noch unbekannter Weg, dessen Aufklärung gewiss eine schwere, aber für die gesamte Menschheit sicherlich ausserordentlich wichtige Aufgabe ist. Für die Kulturvölker des zwanzigsten Jahrhunderts dürfte es ein würdiges Ziel sein, an der Lösung dieser Aufgabe gemeinsam zu arbeiten.

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ÜBER ERDGESCHICHTLICHE KÄLTEPERIODEN.

VON

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EINLEITUNG.

Seitdem man die Anzeichen von Klimaänderungen in der geologischen Vergangenheit erkannte und insbesondere die grosse Ausdehnung von einstigen Inlandeisdecken feststellte, trat die Erklärung des erdgeschichtlichen Klimawechsels in den Vordergrund der paläogeographischen Forschung. Das paläoklimatische Problem, welches zu häufig auch Nichtgeologen in die Diskussion hineinzog, hat eine Unzahl von "Eiszeithypothesen" gezeitigt, von denen jedoch viele den geologischen Tatsachen so wenig Rechnung tragen, dass man sich dem Verdacht nicht entziehen kann, es hätte dem Urheber bloss das eine Ziel vorgeschwebt, die Spekulationen über die Ursachen von Eiszeiten um einen neuen Gedanken zu vermehren oder sich in der Auflösung von mathematischen Aufgaben zu versuchen. Von derartigen Eiszeithypothesen müssen wir selbstverständlich absehen, wenn wir auf dem Boden der durch geologische Einzelforschung gegebenen Tatsachen bleiben und denselben gerecht werden wollen. Schon nach einer flüchtigen Umschau unter den bisherigen Erklärungsversuchen der erdgeschichtlichen Klimawandlungen bleiben nur wenige Hypothesen (eigentlich Gruppen von Hypothesen, wenn wir verschiedene Modifikationen berücksichtigen) zur engeren Wahl übrig. Aber noch von denjenigen Hypothesen, die auf ernsten Grundlagen aufgebaut wurden, erweist sich ein Teil nach näherer Betrachtung als unzulänglich. So ist es zunächst mit der Gruppe von sog. astronomischen Hypothesen der Fall, welche die Eiszeiten durch Änderungen in den Bahnelementen der Erde zu erklären versuchten. Genaue Berechnungen haben gezeigt, dass Schwankungen in der Schiefe der Ekliptik oder in der Exzentrizität der Erdbahn bei weitem keine so durchgreifenden Änderungen im Wärmehaushalt der Erdoberfläche herbeiführen können,[1] wie wir für die durch Eiszeiten registrierten Kälteperioden in der geologischen Vergangenheit verlangen müssen. Es wurde von EKHOLM ausführlich dargetan, dass Schwankungen in der Schiefe der Ekliptik nur Klimaänderungen von kleinerer Amplitude herbeiführen können[2]. Ebenso kommen Polverschiebungen, d.h. entweder Verlegungen der Erdachse oder allmähliche Verschiebungen der äusseren Erdschale, bei der Erklärung der erdgeschichtlichen Klimawand-

[1] HANN, *Handb. d. Klimatologie*, 3 Aufl. (1908), Bd. I., S. 368 ff.
[2] EKHOLM, *On the Variations of Climate*, Quart. Journ. Roy. Meteorol. Soc., Bd. XXVII, 1901, S. 36 ff.

lungen in Betracht, wiewohl diesbezügliche Hypothesen noch heute ihre Anhänger haben. Freilich ist es nicht ausgeschlossen, dass im Laufe der Erdgeschichte die Lage der Pole innerhalb gewisser Grenzen schwankte und nicht mit Unrecht wird angenommen, dass sie zur Diluvialzeit von der gegenwärtigen abwich.[1] Wenn wir aber die paläoklimatischen Probleme mit Polverlegungen erledigen wollten, so „hätten wir — wie KOKEN bemerkt — nicht nur in allen Perioden, nein, in allen Schichten, Spuren der Eiszeit zu erwarten."[2] Indes kommt es bei der Erklärung des Klimawechsels der Vorzeit wesentlich auf die Frage an, warum in gewissen Perioden der Gegensatz der Klimazonen bis zur Ausbildung von Inlandeisdecken sich verschärfte, in anderen Perioden dagegen soweit abgeschwächt wurde, dass man fast von einem gleichmässigen Klima auf der ganzen Erde sprechen kann. Da lassen uns die Polverschiebungen im Stich. Desgleichen versagte auch der Versuch, zu der Verbreitung der Spuren der permischen Vereisung eine entsprechende Lage der Pole zu rekonstruieren.[3]

Nach Ausschaltung der genannten Hypothesen bleiben zur weiteren Betrachtung eine Reihe von Erklärungsversuchen, die ich als die geographischen und die thermischen Hypothesen einander gegenüberstellen möchte. Diese beiden Gruppen von Hypothesen bilden, sozusagen, zwei Lager, in welche gegenwärtig die meisten und die angesehensten Stimmen über die Ursache der erdgeschichtlichen Kälteperioden geteilt sind.

DIE GEOGRAPHISCHEN HYPOTHESEN UND DIE ROLLE DER GEOGRAPHISCHEN FAKTOREN.

Unter dieser Bezeichnung fasse ich die Erklärungsversuche zusammen, welche von der Voraussetzung ausgingen, es seien die erdgeschichtlichen Vereisungen nicht durch eine allgemeine Erniedrigung der Temperatur, sondern durch lokale Vermehrung und Anhäufung von atmosphärischen Niederschlägen in fester Form bedingt gewesen. Letzteres sucht man am einfachsten durch bedeutende Hebungen von einzelnen Teilen der Erdkruste zu erklären (Elevationshypothese). Andere dagegen nehmen für die Eiszeiten eine besondere Verteilung von Land und Meer an, im Zusammenhange womit die Vereisungen auf Änderungen im Verlauf der Meeresströmungen oder in der atmosphärischen Zirkulation zurückgeführt werden. Zunächst haben wir die Tragweite dieser Faktoren zu bewerten.

Für die Beurteilung der Rolle von Hebungen kommt es darauf an, ob wir mit einer regionalen, einheitlichen Inlandeisdecke, oder mit einer lokalen, in getrennte Eisströme differenzierten Gebirgsvergletscherung zu tun haben. Im ersteren Fall kommt die Hebung überhaupt nicht in Betracht, da die grossen Inlandeisdecken nicht von hochgelegenen, sondern im Gegenteil von

[1] HOERNES, *Ältere und neuere Ansichten über Verlegungen der Erdachse*, Mitt. d. Geolog. Ges. in Wien, Bd. I, 1908, S. 197.

[2] KOKEN, *Indisches Perm*, N. Jahrb. f. Mineralogie, etc. Festband. 1907, S. 539.

[3] PENCK, *Die Eiszeiten Australiens*, Zeitschr. d. Ges. f. Erdkunde zu Berlin, Bd. XXXV, 1900, S. 262

relativ flachen Gebieten ausgingen.[1] Bei den lokalen Gebirgsvergletscherungen dagegen ist es ohne weiteres klar, dass eine entsprechende Höhenlage über der Schneegrenze die Entstehung von dauernden Firnanhäufungen vorbestimmte und die unerlässliche Bedingung ihrer Existenz war. Gleichwohl ist die Höhenlage nur als *Prädisposition*, keinesfalls aber als Ursache der Ausbildung von eiszeitlichen Firnansammlungen zu betrachten. Sind doch die Gebirgskerne der Hohen Tatra oder der deutschen Mittelgebirge (Riesengebirge usw.) gegenwärtig nicht vergletschert, obwohl die erhaltenen Teile ihrer präglazialen Hochflächen beweisen[2] dass sie noch heute ungefähr *zur gleichen Höhe* wie in der Diluvialzeit emporragen. Ohne eine entsprechende Depression der Firngrenze, somit ohne eine Erniedrigung der Temperatur, ist die eiszeitliche Vergletscherung von Gebirgen undenkbar.

Die Hypothesen, welche vormalige Vereisungen durch kalte Meeresströmungen bzw. durch Ablenkung von warmen Strömungen im Zusammenhange mit einer geänderten Verteilung von Landmassen erklären wollen, stehen im Widerspruch mit dem gegenwärtig zu beobachtenden Einfluss von Meeresströmungen auf die Vergletscherung der anstossenden Festlandsgebiete. Dass kalte Strömungen nicht eine stärkere Vergletscherung, sondern vielmehr ein trockenes Klima herbeiführen, zeigt am besten das regenarme Küstengebiet von Ecuador und Peru, worauf Philippi mit Recht hingewiesen hat.[3] Eine lokal weitergehende Vergletscherung dagegen tritt nur im Gefolge von warmen Strömungen auf,[4] wie es die bekannten Beispiele von Alaska, Patagonien und Neu-Seeland beweisen. Danach wäre im Falle einer Ablenkung des Golfstromes von der skandinavischen Westküste nicht eine Zunahme, sondern eher ein Rückgang der jetzigen Fjeldvergletscherung zu erwarten.

Ebenso könnten auch durchgreifende Änderungen in der atmosphärischen Zirkulation höchstens nur eine lokale Vergletscherung begünstigen, nie aber eine so weltweite Verbreitung von Vereisungsspuren herbeiführen, wie sie uns der Diluvialzeit vorliegt. Der Annahme, es sei die atmosphärische Zirkulation zur Diluvialzeit von der heutigen verschieden gewesen, widersprechen die Resultate, zu denen die Erforschung der eiszeitlichen Vergletscherung in der einzelnen Gebirgen geführt hat. Es ergab sich überall ein so auffallender Parallelismus der eiszeitlichen und der gegenwärtigen Schneegrenze, dass wir mit Partsch wiederholen dürfen: "Es herrschte dieselbe klimatische Harmonie, nur einige Oktaven tiefer."[5] Eine zeitweise Änderung der atmosphärischen Zirkulation trat erst *in der Folge* der Ausbreitung des nordeuropäischen Inlandeises ein, als an seinem Rande das antizyklonale System von trockenen Winden zur Herrschaft kam. Die

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[1] v. Lozinski, *Über die Lage und die Ausbreitung des nordeurop. dilur. Inlandeises*, N. Jahrb. f. Mineralogie etc., 1911. Bd. II., S. 30 ff.

[2] Über die präglaziale Hochfläche des Riesengebirges vgl. meine Ausführungen im Geolog. Zentralblatt, Bd. XV, Ref. Nr. 33.

[3] Philippi, *Über die peruische Eiszeit*, Zentralblatt f. Mineralogie etc., 1908, S. 359.

[4] Vgl. auch die Ausführungen von G. Becker (Hann, a.a.O.S. 379).

[5] Partsch, *Die Eiszeit in den Gebirgen Europas*, Geograph. Zeitschr., Bd. X, 1904, S. 665.

Hypothese, dass die diluviale Eiszeit durch eine durchgreifende Änderung der atmosphärischen Zirkulation hervorgerufen war, wie sie von Harmer aufgestellt wurde, müsste ferner zur Annahme führen, dass die Vereisung Nordeuropas und Nordamerikas nicht gleichzeitig, sondern alternierend erfolgte, wozu jedoch kein Grund gegeben ist.

Durch die Faktoren, welche in die geographischen Eiszeithypothesen hineingezogen wurden, könnten wir bloss eine Vergletscherung erklären, deren Hinterlassenschaften in kleinerem oder grösserem Umfange lokalisiert wären. Nachdem jedoch die fortschreitende Einzelforschung gezeigt hat, dass die permischen Glazialspuren auf vier Kontinente verteilt sind, diejenigen der diluvialen Eiszeit aber die ganze Erde umspannen, wurden die geographischen Eiszeithypothesen ohne besondere Voraussetzungen unhaltbar. So tauchte die Meinung auf, es seien die eiszeitlichen Gebirgsvergletscherungen in der gemässigten Zone und sogar in den Tropen nicht als eine selbständige Erscheinung, sondern als eine Folge der allgemeinen Abkühlung durch das nordeuropäische und das nordamerikanische Inlandeis zu betrachten.[1] Dass eine ausgedehnte Eisfläche einen erkaltenden Einfluss auf ihre Umgebung ausüben muss, unterliegt keinem Zweifel. Zum Vergleich könnte die erkaltende Wirkung von grösseren Meeresteilen, die durch mehrere Monate des Jahres eine starke Eisdecke tragen (Hudsonbai, Ochotskisches Meer), auf die angrenzenden Teile der Kontinente angeführt werden. Jedenfalls aber müssen einem solchen Einfluss des diluvialen Inlandeises gewisse, nicht allzuweite Grenzen gesetzt werden, und unter keinen Umständen wäre es möglich eine so gewaltige Vergletscherung, wie diejenige der Alpen, oder so entfernte Gletscherspuren der Diluvialzeit, wie in der Balkanhalbinsel und in den Tropen, bloss auf eine Fernwirkung des nordischen Inlandeises zurückzuführen.

Während der von Holst vertretene Gedanke an eine unbeschränkte Fernwirkung des nordischen Inlandeises fast vereinzelt blieb, suchten andere Verfechter von geographischen Eiszeithypothesen der Schwierigkeit, die aus der weltumspannenden Verbreitung von diluvialen Glazialspuren erwuchs, durch die Annahme zu begegnen, dass die diluviale Vereisung nicht überall gleichzeitig war, sondern jeweilig nach Massgabe der in Betracht kommenden geographischen Faktoren (Hebungen u.a.) eintrat. Wenn man behauptet, dass der Anfang und die Dauer der diluvialen Vereisung in verschiedenen Gebieten nicht genau gleichzeitig waren, so ist dieses ohne Zweifel ganz berechtigt und bedeutet eine erwünschte Reaktion gegen den starren, sozusagen alpinozentrischen Standpunkt, wonach der Verlauf der diluvialen Eiszeit in den verschiedensten Gebieten in das Schema der alpinen Phasen hineing-

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[1] Holst, *The Connection of the Glacial Period with Oscillations of the Land*, Geol. Magazine, Dec. 4, Vol. VIII, 1901., S. 214-215.

Wolff, W., *Zur Kritik der Interglazial-Hypothese*, Naturwiss. Wochenschrift, N.F. Bd. II, 1902-3, S. 303.

ungen wird.[1] Nun entsteht aber die Frage, in wie weiten Grenzen die Ungleichzeitigkeit der diluvialen Vereisung sich bewegen kann.

Es ist eigentlich nicht richtig, wenn man von der Gegenwart sagt, dass wir „im Schatten der Eiszeit" leben.[2] Wird doch vom erdgeschichtlichen Standpunkte eine Eiszeit jede Periode genannt, in welcher glaziale Ablagerungen sich bildeten. Danach wäre ein Geologe in der fernen Zukunft vollkommen berechtigt, auch auf unsere Zeit als eine Eiszeit zurückzublicken. Wenn der Nachweis von glazialen Bildungen als ein Kriterium vormaliger Eiszeiten gilt, so müssen, mit W. Ramsay,[3] auch die Gegenwart, wie abgeschwächt ihre Glazialerscheinungen gegenüber der Diluvialzeit auch sind, mit der letzteren zu einer quartären Eiszeit zusammenfassen. Die quartäre Eiszeit in diesem Sinne zeigt tatsächlich eine Ungleichzeitigkeit der Vereisung in verschiedenen Gebieten. In Gebirgen, die eine grössere Höhe erreichen oder in höherer geographischer Breite liegen, muss selbstverständlich eine Vergletscherung früher einsetzen und viel länger dauern, als in niedrigeren oder südlicher gelegenen Gebirgsrücken. In den Alpen dauert die quartäre Eiszeit heutzutage, während sie in den Gebirgen des variskischen Bogens, der Hohen Tatra usw. längst verklungen ist. Auch bei den grossen Inlandeisdecken war die Dauer der tatsächlichen Vereisung von der geographischen Breite des jeweiligen Punktes, bzw. von seiner Entfernung vom Ausbreitungszentrum abhängig, wie ich es an einer anderen Stelle[4] zu veranschaulichen versucht habe. Die Ungleichzeitigkeit, welche für die permischen Glazialspuren in Australien angenommen wird,[5] lässt sich am ungezwungensten in derselben Weise erklären.

Die zeitlichen Abweichungen im Verlauf der quartären Eiszeit können unmöglich dahin ungedeutet werden, dass die Ursache der Firnanhäufung durch lokale, geographische Bedingungen herbeigeführt war. Wenn wir die Eiszeit als eine allgemeine Kälteperiode auffassen, so müssen wir doch als ganz selbstverständlich voraussetzen, dass die sichtbaren Anzeichen der Temperaturerniedrigung nicht überall gleichzeitig auftreten und ihr Ende nehmen, sondern lokale Zeitunterschiede aufweisen werden, je nach Massgabe der *präexistierenden* geographischen Verhältnisse, d.h. der Höhe, der geographischen Breite und der Meeresferne. Mit vollem Recht sagt Hauthal: "Nicht die Eiszeit war lokal beschränkt-die war allgemein-, nur die Wirkungen waren, durch lokale Verhältnisse bedingt, verschieden")[6]. Es braucht kaum

[1] Mit welcher Leichtfertigkeit eine Parallelisierung mi dem alpinen Schema vorgenommen wird, beweist eine Arbeit von Lucerna (*Das Alter der Vulkane des Gesenkes*, Verhandl. d. naturf. Ver. in Brünn, Bd. 48, 1909), worin Flussterrassen, deren Mächtigkeit höchstens einen Meter beträgt, ohne weiteres als "Bühlterrasse" oder "Gschnitzterrasse" bezeichnet werden.

[2] Frech, *Studien über d. Klima d. geolog. Vergangenheit*, Zeitschr. d. Ges. f. Erdkunde zu Berlin, 1902, S. 615.

[3] W. Ramsay, *Orogenesis und Klima*, Öfversigt af Finska Vet. Soc. Forhandl., Bd. 52, A. Nr. 11, Helsingfors, 1910

[4] Mitteil. d. Geolog. Ges. in Wien, Bd. II, 1909, S. 179.

[5] J. W. Gregory, *Climatic Variations*, Compte rendu X. Congr. Géolog. Intern., 1906, S. 420-421.

[6] Hauthal, *Reisen in Bolivien und Peru*, Wiss. Veröffentl. d. Ges. f. Erdkunde zu Leipzig, Bd. VII, 1911, S. 175.

erörtert zu werden, dass ein allmähliches Sinken der Schneegrenze die höher hinaufstrebenden oder in höherer Breite gelegenen Gebirge am ehesten treffen muss. Könnten wir die quartäre Eiszeit nicht vom gegenwärtigen, sondern von einem enfernten Zeitpunkte überblicken, so wäre es leicht einzusehen, dass die lokalen Zeitunterschiede im Vorkommen von Glazialspuren immerhin in bestimmten Grenzen eingeschlossen sind und aus dem Rahmen der erdgeschichtlich scharf abgetrennten Quartärperiode nicht fallen. Die obere Grenze der quartären Eiszeit, zu der wir noch die Gegenwart zu rechnen haben, liegt in der Zukunft. An der unteren Grenze aber finden wir nirgends ein Hinabreichen von Glazialspuren in die Pliozänperiode. Die Annahme, dass der Anfang der quartären Vergletscherung am Südabfall der Alpen in die Pliozänperiode falle, ist von PENCK[1] widerlegt worden und der kürzlich aufgetauchte Gedanke, es hätte die Ausbildung des nordeuropäischen Inlandeises schon in der Pliozänzeit oder noch früher begonnen,[2] entbehrt jeder Begründung.

Die Ansicht von der Ungleichzeitigkeit der quartären Vereisungen hat insbesondere durch die Untersuchungen von J. B. TYRRELL über die Zeitfolge der Glazialablagerung in Kanada[3] an Boden gewonnen. Indes scheint die Ungleichzeitigkeit der Vereisung in Nordamerika nicht so weit zu gehen, wie es Tyrrell gefolgert hat, indem er ein allmähliches Vorrücken der Vereisungsherde von Westen nach Osten annahm.[4] Ich möchte der Auffassung von TYRRELL die folgende gegenüberstellen. Dass zuerst die quartäre Vergletscherung des gebirgigen Westens eintrat, ist ganz selbstverständlich, da eine allmähliche Erniedrigung der Temperatur und der Schneegrenze am allerersten die höher gelegenen Teile der Erdkruste betreffen muss. Erst später, als die Abkühlung vorgeschritten war, konnte im Osten, im flachen Gebiete des Laurentischen Plateaus eine ausgedehnte Inlandeisdecke sich herausbilden. Das Inlandeis rückte nach Westen bis an das Felsengebirge heran und drängte seine Vorlandvergletscherung zurück. Dasselbe war in Skandinavien der Fall, wo zunächst eine Vorlandvergletscherung durch die Firnanhäufung im Hochgebirge zustande kam und nachher durch das von Osten herantretende Inlandeis verdrängt wurde. Es haben ferner die Untersuchungen von TYRRELL gezeigt, dass die Ausbreitung des nordamerikanischen Inlandeises zuerst vom Keewatiner Zentrum im Westen der

[1] *Die Alpen in Eiszeitalter*, Bd. III, S. 777, 806.

[2] KRISCHTAFOWITSCH, *Sur la dernière période glaciaire*. Bull. de la Soc. Belge de Géologie etc. Bd. 24, 1910, S. 294, 295.

Das Vorkommen von Fragmenten kristallinischer Gesteine (wohl aus dem Grundgebirge der ukrainischen Platte) im oberpliozänen Kalk von Odessa, worauf sich Krischtafowitsch beruft, kann höchstens auf einen Transport durch das Grundeis der Flü[illegible] hindeuten und würde somit die herrschende Ansicht bestätigen, dass eine allmähl[illegible] Temperaturerniedrigung bereits zur Pliozänzeit einsetzte.

[3] J. B. TYRRELL, *The Glaciation of North Central Canada*, Jour. Geol., Vol. VI, 1898.

[4] CALHOUN (*The Montana Ice Lobe*. Prof. Papers U.S. Geol. Survey. No. 50, 1906, p. 54) ist dagegen zu dem Ergebnis gekommen, dass sowohl die Vergletscherung des Felsengebirges, wie auch die Ausbreitung des Inlandeises vom Keewatiner Zentrum in dieselbe Kälteperiode fallen.

Hudsonbai aus erfolgte, und bereits erheblich zurückgegangen war, als das Labradorische Ausbreitungszentrum im Osten der Hudsonbai zur vollen Geltung kam. Aus einer solchen Verlegung des Ausbreitungszentrums der nordamerikanischen Inlandeisdecke kann man jedoch nicht den Schluss ziehen, dass auch der Einfluss derjenigen Faktoren, welche die Entstehung des Inlandeises bedingten, im Laufe der Zeit sich verschoben hätte. Denn es darf dieses Problem nicht in der Weise aufgefasst werden, als sei von jedem der beiden Zentren je eine Inlandeisdecke in gewissem Zeitabstand ausgebreitet worden. Vielmehr haben wir hier mit der Erscheinung zu tun, dass im Bereiche *einer* Inlandeisdecke, nachdem ihre Ausbildung durch eine Temperaturerniedrigung einmal bestimmt war, mit der Zeit die Lage des Ausbreitungzentrums sich verschob, und zugleich die Ausdehnung sowie die Begrenzung des nordamerikanischen Inlandeises eine erhebliche Änderung erfuhr. Am nächsten liegt der Gedanke, dass diese Änderungen innerhalb der nordamerikanischen Inlandeisdecke durch geophysikalische Faktoren herbeigeführt wurden. Wie weit die Lage und die Ausbreitung eine Inlandeisdecke, sobald klimatische Bedingungen ihre Entstehung ermöglichen, von der Massenverteilung auf der Erdoberfläche geregelt werden, habe ich an dem Beispiele des nordeuropäischen diluvialen Inlandeises darzulegen versucht.[1]

Es wäre ferner noch folgendes über den Begriff des „Ausbreitungszentrums" einer Inlandeisdecke zu bemerken. Man soll sich dasselbe nicht etwa in der Weise vorstellen, als wenn die Wirkungen der Temperaturabnahme nur dieses relativ sehr kleine Areal als einen sozusagen Angriffspunkt betreffen und auf demselben eine übermässig anschwellende Firnanhäufung veranlassen würden. Das Ausbreitungszentrum ist nur das Gebiet, von dem die Eisbewegung nach allen Seiten ausstrahlte. Da die Gegenwart uns kein Beispiel einer Inlandeisdecke *in statu nascendi* bietet, sind über das Werden eines Inlandeises bloss Spekulationen möglich. Ich möchte annehmen, dass Inlandeisdecken—nachdem die erforderliche Temperaturerniedrigung gegeben war—aus der Firnanhäufung in ausgedehnten, relativ flachen Gebieten hervorgegangen sind. Als die Eisdecke zunahm, trat allmählich das seitliche Abfliessen des Eises in allen Richtungen nach Massgabe der orographischen Gestaltung der umrandenden Gebiete ein. Dabei musste selbstverständlich ein zentrales Gebiet bleiben, von welchem die allseitige Bewegung des Eises scheinbar ausging und gegen welches zu die Schrammrichtungen in der felsigen Unterlage konvergieren. Meines Erachtens nach war die Lage dieses zentralen Gebietes wie auch seine Gestalt, ob es ein dem geometrischen Ideal gleichkommendes "Zentrum" oder eine langgezogene Eisscheide bildete—nicht durch den lokalen Maximalbetrag der Temperaturabnahme, sondern vielmehr durch die orographischen und geophysikalischen Bedingungen der Ausbreitung des Inlandeises bestimmt. Mit der Zeit konnten die geophysikalischen Faktoren der Eisausbreitung eine Änderung erfahren und infolgedessen auch eine Verlegung des zentralen Gebietes erfolgen, wie es mit dem nordamerikanischen Inlandeis der Fall war.

[1] V. Lozinski, *Über die lage, u.s.w.*, S. 37 ff.

DIE PERMISCHE EISZEIT.

Wenn die vorstehenden Ausführungen gegen die geographischen Hypothesen gerichtet waren, so soll anderseits die Rolle, welche die geographischen Faktoren für den lokalen Verlauf einer Vergletscherung oder Vereisung haben, nicht übersehen werden. Von geographischen Faktoren hängt der Umfang und die Dauer einer Vereisung ab. Sie entscheiden ferner, ob überhaupt bei einer Temperaturerniedrigung die dauernde Firnanhäufung eintritt, wie es das Beispiel des zur Diluvialzeit nicht vereisten Nordasien zeigt. Dem lokalen Einflusse geographischer Faktoren ist es zuzuschreiben, dass die Verbreitung der heutigen wie der diluvialen Gletscher bzw. Inlandeisgebiete in Bezug auf die Pollage eine so unregelmässige und vom Verlauf der Klimazonen abweichende Anordnung aufweist, wie es v. KERNER[1] betont hat. In viel höherem Grade ist letzteres mit der Verteilung der permischen Glazialspuren der Fall, so dass man immer wieder zu der Ansicht verleitet wird, es sei die permische Vereisung lediglich auf geographische Faktoren zurückzuführen. Dass die allgemeine Abkühlung der Permzeit nur im Bereiche des indoafrikanischen Kontinentes die Ausbildung von Inlandeisdecken zur Folge hatte, kann zum Teil der Mitwirkung von geographischen Faktoren zugeschrieben werden. Anderseits aber ist noch der Umstand in Betracht zu ziehen, dass die Ausbildung von regionalen Vereisungen neben allgemein klimatischen Bedingungen auch durch geophysikalische Faktoren bestimmt werden konnte, worauf der innige Zusammenhang der vorzeitlichen Inlandeisdecken mit Gebieten, die unmittelbar vorher eine langdauernde, tiefgreifende Abtragung erfahren haben, mit aller Wahrscheinlichkeit hinzuweisen scheint.[2]

Bei der Beurteilung der geographischen Verbreitung von Spuren einer so weit zurückliegenden Eiszeit wie die permische muss noch die relative Erhaltungsfähigkeit von Glazialspuren in Betracht gezogen werden. Auch in dieser Hinsicht ist zwischen Vereisung und Vergletscherung zu unterscheiden. Für eine ausgedehnte Vereisung, die in einem flachen Gebiete sich ausbreitet und eventuell bis zum Meere reicht, ist die Chance viel grösser, dass ihre Ablagerungen in der Schichtenfolge sich erhalten werden. Eine Vergletscherung dagegen, mag sie von getrennten Karmulden oder von einem fjeldartigen Firnplateau genährt werden, hinterlässt ihre morphologischen Spuren und Absätze im Innern des Gebirges bzw. Hochplateaus. Soweit die Glazialspuren über den Gebirgsrand nach aussen nicht hinausgreifen, werden sie bei der späteren Abtragung und Einebnung des Gebirges selbstverständlich für die geologische Überlieferung vollständig verloren gehen. Wenn aber der reichliche Eisabfluss zu einer flächenhaften Vorlandvergletscherung führt, so sind dadurch—was *die Entstehung der Glazialablagerungen* anlangt—auf kleinem Raume ungefähr dieselben Bedingungen gegeben, wie sie eine regionale Inlandeisdecke in einem weit grösseren Umfange hervorbringt.

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[1] v. KERNER, *Sind Eiszeiten durch Polverschiebungen zu erklären?* Verhandl. d. k. k. geolog. Reichsanstalt in Wien, 1909. S. 265-266.

[2] v. LOZINSKI, a. a. O., S. 33-35.

Die Aufschüttungen, die in diesem Falle deckenartig im flachen Vorlande ausgebreitet werden, sind, im Gegensatz zu den Glazialspuren im Innern des Gebirges, in viel geringerem Grade der Gefahr ausgesetzt, nachher der Abtragung vollständig anheimzufallen. Bedenkt man die weitgehende Verebnung, welche die Gebirgserhebungen der Vorzeit erfahren haben, so wird es ganz klar, dass nur von grossen Inlandeisdecken sowie von flächenhaften Vorlandsvergletscherungen aus den weit zurückliegenden Perioden Glazialspuren in der Schichtenfolge sich erhalten konnten.

Was wir von der Verbreitung der unzweideutigen Glazialablagerungen aus der Permzeit wissen, deutet allenthalben auf ausgedehnte Inlandeisdecken hin. Nun drängt sich die Frage auf, ob nicht auch die Gebirgserhebungen der Permzeit vergletschert waren. Es lässt sich weder dafür noch dagegen der Beweis erbringen, nachdem die damaligen Gebirge in den darauffolgenden Perioden bis zum innersten Mark abgetragen wurden. Die Möglichkeit aber, dass die Gebirge der Nordhemisphäre zur Permzeit vergletschert waren, ist meines Erachtens garnicht ausgeschlossen[1] und würde die scheinbar abnorme Verteilung der bisher bekannten permischen Glazialspuren auf der Erde wesentlich ergänzen. Bei dem vereinzelten, neuerdings von Frech gewürdigten Geschiebefund im tiefsten Rotliegenden von Westfalen,[2] den Philippi mit zu grosser Entschiedenheit als eine pseudoglaziale Erscheinung bezeichnete,[3] ist eine glaziale Entstehung doch möglich. Freilich muss die lokale Beschränkung dieses Vorkommens noch ein gewisses Bedenken erregen. Es ist aber zu erwägen, ob die Geröllmassen, aus denen die Konglomerate des Rotliegenden aufgeschüttet wurden, wirklich in ihrer ganzen Ausdehnung *rein fluviatiler Herkunft* sind, wie man ganz allgemein annimmt. Mit vollem Recht wird hervorgehoben, dass die fluvioglazialen Deckenschotter im Alpenvorlande die vollkommenste Ähnlichkeit mit Schotterflächen, die am Rande von nicht vergletschert gewesenen Gebirgen durch Flüsse aufgeschüttet wurden, zeigen und von solchen kaum zu unterscheiden sind.[4] Die fluvioglaziale Entstehung von Schotterfeldern im Vorlande wird lediglich durch ihre innigste Verbindung mit Moränen an den Talaustritten verbürgt. Denken wir uns aber die Alpen mit ihrem ganzen Schatz von Glazialspuren vollständig eingeebnet, so werden bloss die Schotterdecken im Vorlande übrig bleiben, die in der Tat „eine glaziale Fernwirkung"—wie *Penck*[5] sie nennt—darstellen, die jedoch als solche nach Abtragung der dazu gehörigen Glazialspuren im Gebirge kaum erkannt werden könnten. So möchte ich es für sehr wahrscheinlich halten, dass die Konglomerate des Rotliegenden *zum Teil und jedenfalls in beschränktem Umfange* als eine fluvioglaziale Ablagerung im Vorlande der variskischen Gebirge nach

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[1] Den gleichen Standpunkt vertritt Philippi, *Über einige paläoklimatische Probleme*, N. Jahrb. f. Mineralogie u.s.w. Beil. Bd. XXIX, 1910, S. 129.

[2] Frech, *Über das Klima der geolog. Perioden*, Ebda. 1908. II. S. 76-77.

[3] Philippi, Ebda., S. 127-128.

[4] Hilber in Zeitschr. f. Gletscherkunde. Bd. IV, S. 71, 304.—Cholnoky, *Studienreisen in der Schweiz*, Bull. de la Soc. Hongr. de Géographie, Bd. XXXVI, 1908. S. 223-224.

[5] *Alpen im Eiszeitalter*, Bd. I. S. 113.

Art der subalpinen Deckenschotter entstanden sind.[1] Da das Rotliegende mit Porphyrergüssen verknüpft ist, konnte man an eine ähnliche Beeinflussung der fluvioglazialen Akkumulation durch Vulkanausbrüche denken, wie sie bei den Sandrbildungen Islands zur Geltung kommt und auch für die „Rollsteinformation" Patagoniens[2] angenommen wird. Gibt man nun die Möglichkeit einer zum Teil fluvioglazialen Entstehung der Konglomerate des Rotliegenden zu, so rückt der vereinzelte Geschiebefund von Westfalen in ein anderes Licht. Es ist denkbar, dass während der fluvioglazialen Akkumulation im Vorlande ein Gletscher, dank besonders günstiger Bedingungen, weiter aus dem variskischen Gebirge hinaustrat und den lokal beschränkten Moränenrest hinterliess.

DIE DIASTROPHISCHEN PERIODEN.

Die Elevationshypothese, welche die vorzeitlichen Vergletscherungen lediglich durch eine bedeutende Hebung des betreffenden Gebietes erklären möchte, scheitert an der Tatsache, dass die Glazialspuren der Diluvialzeit eine weltweite Verbreitung aufweisen, und auch die Ausdehnung der permischen Eiszeit weit über die Grenzen einer lokalen Erscheinung hinausgeht. Dieser Schwierigkeit versucht W. Ramsay zu begegnen, indem er meint, es hätten die "orogenetischen Phasen," in denen der grösste Teil der Erdoberfläche von Krustenbewegungen erfasst wurde, infolge der weitgehenden Verschärfung des Reliefs der Kontinente eine *allgemeine* Verschlechterung des Klimas auf der ganzen Erde herbeigeführt.[3] Dass in gewissen Abschnitten der Erdgeschichte, die ich als *diastrophische Perioden* bezeichnen möchte, Krustenbewegungen in einem sehr grossen Umfange eintraten und dass dadurch die klimatischen Verhältnisse, in erster Linie die Niederschlagsverteilung beeinflusst wurden, unterliegt keinem Zweifel. Es ist jedoch eine allgemeine, für die Eiszeiten erforderliche Temperaturerniedrigung in der *unmittelbaren* Folge von diastrophischen Perioden kaum anzunehmen. Wenn wir die gegenwärtige Erhebung der Kontinente ins Auge fassen, so geht Asien voran, dessen mittlere Höhe ungefähr dreimal so gross ist als die Europas und noch diejenige von Nordamerika erheblich übersteigt. Gleichwohl bleibt Asien an Ausdehnung der gegenwärtig eisbedeckten Gebiete weit hinter Europa und Nordamerika zurück.[4] Zur Diluvialzeit, als grosse Teile von Europa und Nordamerika mit Inlandeis bedeckt wurden, war dieser Gegensatz noch viel schärfer ausgeprägt. Anderseits ist darauf hinzuweisen, dass die jüngste Kreidezeit, für die wir aus dem grossen Umfange der oberkretazischen Transgression eine weitgehende Einebnung der Landflächen zu folgern

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[1] Bei der bedeutenden Mächtigkeit der Konglomerate des Rotliegenden muss man allerdings eine Senkung des der Verschotterung unterworfenen Gebirgsvorlandes voraussetzen, wie es Penck und Brückner (*Alpen im Eiszeitalter*, Bd. III, S. 792-793, 889, von über 200 m erreicht.

[2] O. Nordenskjöld, *Die Polarwelt*, 1909. S. 107-108.

[3] W. Ramsay, a. a. O.

[4] Vgl. die Zusammenstellung in Hess, *Die Gletscher*. 1904. S. 114.

haben, doch eine Periode allmählicher Klimaabkühlung war. So sprechen Tatsachen gegen einen direkten Zusammenhang von Hebungen und Kälteperioden. Es drängt sich aber die Frage auf, ob die diastrophischen Perioden *indirekt* eine allgemeine Temperaturerniedrigung veranlassen können. Ein solches nahm CHAMBERLIN an, indem er mit diastrophischen Perioden einen gesteigerten Verbrauch des atmosphärischen Kohlensäure durch die Zersetzung der Silikate und durch die Auflösung von Kalk in Zusammenhang brachte.[1]

Bekanntlich haben zweimal im Laufe der Erdgeschichte,[2] in der jungpaläozoischen Zeit und in der Mitte der Tertiärzeit, Schichtenfaltungen in ausgedehntem Umfange stattgefunden. Solange man die Entstehung der orographischen Erhebungen mit der Faltung ursächlich verknüpfte, galten jene beiden Phasen der Schichtenfaltung zugleich als Perioden der Gebirgsbildung, in denen das Relief der Erdoberfläche eine bedeutende Verschärfung erfahren sollte. Indes haben die neueren Forschungen gelehrt, dass die Auftürmung der Gebirge mit der Schichtenfaltung nicht zusammenfällt, dass vielmehr letztere grösstenteils auf dem Meeresboden sich vollzog. Die Heraushebung der Gebirge dagegen geschah durch vertikale Bewegungen, von denen die bereits gefalteten Schichtenkomplexe nachträglich manchmal erst nach einem grösseren Zeitintervall ergriffen wurden. Wir dürfen daher die Phasen der ausgedehnten Schichtenfaltungen nicht zugleich als Perioden einer hochgradigen Akzentuierung des Reliefs der Erdoberfläche ansprechen. Wenn es auf die Beurteilung des Reliefs der Erdoberfläche in den vergangenen Perioden ankommt, so wären dazu Schwankungen der Meereshülle am meisten geeignet. Eine Transgression von bedeutender Ausdehnung deutet jedenfalls darauf hin, dass die Festlandsgebiete in grösserem Umfange einer Überflutung zugänglich waren, somit im Zustande einer fast vollkommenen Verebnung sich befanden (base-level periods im Sinne von CHAMBERLIN[3]). Umgekehrt können wir aus weitgehenden Regressionen der vorzeitlichen Meere schliessen, dass grosse Teile der Erdoberfläche von nicht unerheblichen Hebungen betroffen wurden (diastrophische Perioden).

Wenn wir in der geologischen Vergangenheit Umschau halten, so finden wir in der Tat, dass die Eiszeiten meistens in die Perioden der zurückgehenden Meeresbedeckung fallen. Es wäre aber voreilig, aus dem zeitlichen Zusammenfallen von Vereisungen mit den Meeresregressionen, bzw Krustenhebungen von grösserem Umfange auf eine ursächliche Abhängigkeit zu schliessen,[4] wie es Chamberlin tat, indem er für die Perioden zurückgehender Meeresbedeckung einen gesteigerten Verbrauch der atmosphärischen Kohlen-

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[1] T. C. CHAMBERLIN, *Hypothesis of Cause of Glacial Periods*, Jour. Geol., Vol. VII, 1899, pp. 564, 583.

[2] Abgesehen von der präkambrischen Zeit.

[3] CHAMBERLIN, a. a. O., S. 584.

[4] Gewiss scheint die oberkretazische Abkühlung am Schlusse der Kreidezeit, also ungefähr während einer Regressionsphase, ihren tiefsten Punkt zu erreichen. Man muss aber beachten, dass die oberkretazische Abkühlung bereits seit dem Cenoman sich fühlbar machte, gleichzeitig mit der oberkretazischen Transgression, die durch ihre Ausdehnung auf eine weitgehende Verebnung der Kontinente hinweist.

säure durch die Auflösung von Kalk und die Zersetzung von Silikaten voraussetzte.[1] Bei der Betrachtung der Kohlensäurehypothese in einem folgenden Abschnitt wird der Eintritt von Eiszeiten in der geologischen Vergangenheit noch einen anderen, meines Erachtens viel wichtigeren Zusammenhang ergeben. Bedeutet doch der Verbrauch der Kohlensäure durch Zersetzung bzw. Auflösung der Gesteine auf der Landoberfläche noch nicht einen Verlust der Atmosphäre, da er von der gleichzeitigen Kalkabscheidung durch Organismen in den Meeren gewiss aufgewogen wird. Vom Standpunkte der Kohlensäurehypothese konnten nur die ältesten, präkambrischen und kambrischen Vereisungen durch den gesteigerten Verbrauch der atmosphärischen Kohlensäure infolge von ausgedehnten Landhebungen erklärt werden. In der ausserordentlich bewegten Zeit des Präkambriums und des Kambriums fand eine Kalkausscheidung aus dem Meerwasser durch Organismen in grösserem Mass noch nicht statt und infolgedessen gab es auch keinen Ersatz der Kohlensäure, die bei der Zersetzung von Silikaten auf den Landflächen der Atmosphäre entzogen und in löslichen, dem Meere zugeführten Verbindungen gebunden wurde. Ich möchte der Ansicht von Daly entgegentreten, es sei das präkambrische Meerwasser kalkfrei gewesen.[2] Mit viel grösserer Wahrscheinlichkeit wäre anzunehmen, dass das Meerwasser bereits zur präkambrischen Zeit einen gewissen Kalkgehalt besass, die Meeresorganismen dagegen die Fähigkeit der Kalkabscheidung sich noch nicht angeeignet haben. Seitdem aber zur Silurzeit die Kalkausscheidung durch Meeresorganismen in vollem Umfange einsetzte, bieten die dabei frei werdenden Kohlensäuremengen einen reichlichen Ersatz des Verlustes, welchen die Auflösung von Kalk und die Zersetzung von Silikaten auf der Landoberfläche herbeiführt.

DIE LOKALEN UND ERDUMSPANNENDEN EISZEITEN.

Die Eiszeiten, die durch Ablagerungen glazialen Ursprunges überliefert wurden, stellen lediglich die extremsten Kälteperioden der geologischen Vergangenheit dar. Ausserdem aber finden wir in der Vorzeit auch Perioden mit schwächerer Temperaturerniedrigung, die zu Vereisungen auf der Erdoberfläche nicht führten und durch keine oder höchstens lokale Glazialspuren registriert wurden. In Ermangelung von glazialen Bildungen kann man solche schwächere Kälteperioden zunächst aus den Veränderungen der Tier- und Pflanzenwelt vermuten. So ist eine Temperaturerniedrigung für die Liaszeit anzunehmen, worauf die Betrachtungen über fossile Insekten hinweisen.[3] Diese Abkühlung des Klimas an der Wende der Trias- und Liaszeit war von allgemeinem Charakter und hat auch die Meeresorganismen betroffen, sodass eine tiefgreifende Umprägung der Ammonitenfauna erfolgte. Eine ähnliche Abkühlung des Klimas, die zu Ende der Kreidezeit ihren

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[1] Chamberlin, a. a. O., S. 568-569.

[2] Daly, *The limeless Ocean of Precambrian Time.* Am. Journ. of Science. Vol. 173, 1907, p. 113.
Vgl. hierzu Steinmann, *Die kambrische Fauna*, Geolog. Rundschau, Bd. I, 1910, S. 72.

[3] Handlirsch, *Die fossilen Insekten*, 1908. S. 1168-1169.

tiefsten Punkt erreicht hat, kommt ebenfalls in der einschneidenden Umbildung der organischen Welt zum Ausdrucke.[1] In paläogeographischer Beziehung ist die Abkühlung an der Grenze der Trias- und Liaszeit, wie auch diejenige der jüngeren Kreidezeit durch das Eindrigen von mitteleuropäischen Faunenelementen in die mediterrane Region ausgezeichnet. Die liassische Fauna der Nordalpen zeigt bekanntlich einen überwiegend mitteleuropäischen Charakter. Ebenso dringen in der oberen Kreide mitteleuropäische Formen in das Karpatengebiet vor[2] und erreichen erst in Kleinasien unter 41° n. Br. die Südgrenze ihrer Verbreitung.[3]

Neben Verschiebungen und Veränderungen der Organismen dürfen unter Umständen auch gewisse lithogenetische Merkmale als Anzeichen von Kälteperioden verwendet werden. Eine regellose Verstreuung von Geröllen in feinklastischen oder kalkigen Ablagerungen kann manchmal auf einen Transport durch das Grundeis der Flüsse,[4] somit auf eine Abkühlung des Klimas hindeuten. Es ist aber in solchen Fällen die grösste Vorsicht geboten, da der Transport von derartig verstreuten Geröllen ebensogut z. B. durch flottierendes Wurzelgeflecht sich erklären lässt[5]. Das sicherste lithogenetische Merkmal von Abkühlungsperioden bietet die weitverbreitete Ablagerung von feldspathaltigen, detritären Sedimenten, wie ich es bezüglich der Arkosen des Rotliegenden zu begründen versuchte[6]—insofern der Feldspatdetritus einen längeren Transport von seinem Ursprungsort *in unzersetztem Zustande* zu überstehen hatte. Nun finden wir, dass das *regionale* Vorkommen von Arkosen, bzw. von klastischen Ablagerungen mit reichlichem z. T. kaolinisiertem Feldspatdetritus auf das genaueste mit Perioden einer Klimaabkühlung sich deckt. Die unterpermischen Arkosen, die eine weltweite Verbreitung haben, fallen mit einer ausgedehnten Vereisung zusammen. Ausserhalb Europas, wo permische Glazialkonglomerate sich erhalten haben, lässt sich der zeitliche Zusammenhang der Arkosenbildung mit der Vereisung direkt beweisen.[7] Während der mesozoischen Zeit hat zweimal eine weitverbreitete Akkumulation von Arkosen stattgefunden, zunächst im Unterlias, wozu die Arkosen in den Grestener Schichten der Nordalpen und der feldspatreiche Hörsandstein Schonens gehören, dann aber in der oberen Kreide (Kaolin-

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[1] FRECH, *Die wichtigsten Ergebnisse der Erdgeschichte*, Geograph. Zeitschr., Bd. XI, 1905, S. 74.

[2] WISNIOWSKI, *Über die obersenone Flyschfauna von Leszczyny*. Beiträge zur Geol. u. Paläont, Öst.-Ung., Bd. XX, 1907, S. 204.

[3] FRECH, Geolog. *Beob. im pontischen Gebirge*. N. Jahrb. f. Mineralogie u.s.w., 1908. Bd. I, S. 11.

[4] Wie KALKOWSKY für einen bestimmten Fall annahm. Vgl. Zeitschr. d. Deutsch. Geolog. Ges., Bd. XLV, 1893, S. 83.

[5] Vgl. FELIX, *Über einige norddeutsche Geschiebe*. Sitzungsber. d. Naturf. Ges. zu Leipzig, (3 Febr. 1903).

[6] v. LOZINSKI, *Zur Bildungsweise der Konglomerate des Rotliegenden*, Jahrb. d.k.k. Geolog. Reichsanstalt, Bd. LXII, 1912, S. 214-215.

[7] Man beachte das Vorkommen von Feldspatdetritus in der Talchir-Stufe (vgl. KOKEN, Indisches Perm u.s.w., S. 492). Nach GUILLEMAIN (Zeitschr. d. Deutsch. Geolog. Ges., Bd. LXIII, 1911. Monatsber. S. 217) wird in Uruguay das permische Glazial unmittelbar von Arkosen überlagert.

sandstein in der spanischen Provinz Valencia,[1] Arkosen und „kaolinische Sandsteine" in Kleinasien[2]). Die regionale Arkosenbildung im Unterlias und in der Oberkreide war, aller Wahrscheinlichkeit nach, durch eine Klimaabkühlung bedingt, die wir im vorstehenden für diese beiden Zeitabschnitte aus dem Verhalten der organischen Welt gefolgert haben. Es ist nicht ausgeschlossen, dass auch die Akkumulation der unterdevonischen Arkosen der Ardennen ("arcose d'Haybes") mit einer Klimaabkühlung zusammenhing, insofern das unterdevonische Alter der Glazialspuren aus der "Table Mountain series" in Südafrika sich bestätigen würde.

In Anbetracht der schon früher hervorgehobenen Beispiele aus der Gegenwart (Alaska u.a.), wonach durch besondere Bedingungen eine ausnahmsweise tief, sogar bis zum Meeresniveau hinabgehende Vergletscherung hervorgerufen wird, haben wir mit der Möglichkeit zu rechnen, dass die geographischen Faktoren unter günstigen Umständen eine *lokale* Eiszeit herbeiführen können. Während einer Abkühlung des Klimas, die zu schwach war, um Vereisungen von grösserer Ausdehnung hervorzubringen, konnte durch das örtliche Zusammenfallen von geographischen Faktoren, wie z. B. das Herantreten von wärmeren Meeresströmungen an gebirgige Küstenstriche, dennoch eine lokale Eiszeit zustande kommen. Wenn wir Spuren von Eiszeiten aus der geologischen Vergangenheit bewerten wollen, so müssen wir zwischen *allgemeinen* (regionalen) und *lokalen* Eiszeiten unterscheiden. Die Hinterlassenschaften der ersteren sind über einen grossen Teil der Erdoberfläche verbreitet, wie es für die permische und die quartäre Eiszeit der Fall ist. Von lokalen Eiszeiten dagegen kommen nur vereinzelte, räumlich beschränkte Spuren vor. Als eine solche lokale Eiszeit ist die unterdevonische Vereisung aufzufassen, deren Spuren nur aus der "Table Mountain series" in Südafrika bekannt sind.[3] Es ist möglich, dass während einer jedenfalls nicht allzu weitgehenden Abkühlung, die zur unterdevonischen Zeit stattgefunden zu haben scheint, worauf die Differenzierung der Meeresprovinzen im Unterdevon hindeutet, infolge besonders günstiger geographischer Bedingungen eine lokale Vereisung sich herausbilden konnte. Der Abkühlung an der Grenze der Trias- und Liaszeit dürfte jene lokale Vereisung in Zentralafrika entsprechen, deren Spuren im Niveau der "Lubilache Formation" gefunden wurden.[4] Ob auch die Abkühlung, die am Schlusse der Kreidezeit ihren tiefsten Punkt erreichte, zu einer lokalen Vereisung führte, ist sehr fraglich, und es werden die angeblichen Glazialspuren aus der Oberkreide von Austra-

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[1] Nach Ewald (Zeitschr. d. Deutsch. Geolog. Ges., Bd. LXIII, 1911, S. 410).

[2] Berg. Geolog. Beob. in Kleinasien, Ebda. Bd. LXII, 1910, S. 489, 511. Frech, *Geolog. Beob. im pont. Gebirge*, S. 3. Kossmat, *Geolog. Unters. des Vilajets Trapezunt*, Mitteil. d. Geolog. Ges. in Wien, Bd. III, 1910. S. 224.

[3] Rogers—Du Toit, *Introduction to the Geol. of Cape Colony.* 2nd Ed., 1909, p. 133.

[4] Ball-Shaler. A. *Central African Glacier of Triassic Age.* Jour. Geol., Vol. XVIII, 1910.

lien[1] und von Spitzbergen[2] nicht mit Unrecht angezweifelt. Sollte einmal bei genauerer Untersuchung die glaziale Natur unzweideutig festgestellt werden, so würde ebenfalls ein Beispiel von lokalen Eiszeiten vorliegen.

Inwieweit die ältesten Eiszeiten von einem regionalen oder lokalen Charakter waren, lässt sich vorläufig nicht mit aller Sicherheit entscheiden. Es scheint aber die präkambrische Eiszeit von einem allgemeinen Charakter gewesen zu sein, während die kambrischen Glazialspuren vielleicht von lokalen Vereisungen herrühren.

Vom Standpunkte eines allmählichen Wärmeverlustes der Erde wird auch die Ansicht vertreten, es hätten „im Laufe der Erdgeschichte die Vereisungen an Intensität zugenommen".[3] Eine solche Annahme ist nicht begründet. Nach dem Gesagten treten zwischen der permischen und der Quartären Eiszeit zwei Perioden der Abkühlung (Lias, Oberkreide) von kleinerer Amplitude hervor. Es ist daher irgend eine konstante Intensitätszunahme der erdgeschichtlichen Kälteperioden nicht vorhanden.

DIE KOHLENSÄUREHYPOTHESE.

Die fortschreitende Untersuchung der diluvialen Gebirgsvergletscherungen, insbesondere der Alpen (nach Penck[4]), führt immer wieder zu dem Ergebnis, dass die eiszeitliche Firnanhäufung nicht durch übermässige Zunahme der Niederschläge, sondern durch eine Temperaturerniedrigung zu erklären ist. Ebensowenig trifft die Annahme zu, es sei das nordeuropäische Inlandeis nach Art der heutigen Vorlandsvergletscherung in Alaska in Gegenden mit üppigem Waldwuchs vorgedrungen. Durch die Entdeckung einer arktischen Diluvialflora im nordöstlichen Galizien zwischen 50° und 50° 30′ n. Br.[5] wird die Ansicht von Nathorst, „dass eine Glazialflora auch den äussersten Rand des grossen nordischen Landeises umsäumt hat",[6] in vollem Umfange bestätigt. Angesichts der immer mehr sich häufenden Tatsachen müssen wir die diluviale Eiszeit und die älteren Eiszeiten als Kälteperioden ansprechen. Zur Erklärung der letzteren bleibt nur eine engere Wahl zwischen Änderungen der von der Sonne eingestrahlten Wärmemenge und der Kohlensäurehypothese übrig.

Die Ansicht, dass Eiszeiten eine Folge von Änderungen der von der Sonne zukommenden Wärmemenge waren, wurde neuerdings sowohl von geologischer,[7] wie auch von meteorologischer[8] Seite in den Vordergrund

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[1] Bas[illegible], *Beiträge zur Geol. Australiens*, Zeitschr. d. Deutsch. Geolog. Ges., Bd LXI, 1909, [illegible]

[2] Garwo[illegible] Gregory, *Contributions to the glacial Geol. of Spitzbergen.* Quart. Journ. of the Ge[illegible] Soc., Vol. LIV, 1898, p. 217.

[3] v. Wolff, *Die vulkan. Kraft*, Zeitschr. d. Deutsch. Geolog. Ges., Bd. LX, 1908, S. 476.

[4] *Alpen im Eiszeitalter*, Bd. III, S. 1145-1146.

[5] Szafer in Bull. Acad. d. Sc. de Cracovie, Ser. B, 1912.

[6] Nathorst, *Die Entdeckung einer fossilen Glazialflora in Sachsen*, Ofversigt of Kongl. Vetenskaps Akad. Förhandl., Jg. LI, Stockholm, 1894, S. 540.

[7] Philippi, *Über einige palaeoklim. Probleme*, u.s.w., S. 168 ff.

[8] Arctowski, *L'Enchainement des variations climatiques*, 1909. S. 36.

gestellt. Dass in der Vorzeit die Menge der von der Sonne ausgestrahlten Wärme Schwankungen unterliegen konnte, ist kaum zu leugnen. Wir haben aber kein Mittel noch einen Anhaltspunkt, um solche Änderungen im Laufe der Erdgeschichte zu kontrollieren[1] und auf ihre Brauchbarkeit für die Erklärung von Eiszeiten zu prüfen. Es wäre noch zu beweisen, ob Schwankungen der Sonnenstrahlung von solcher Amplitude und von solcher Dauer sein konnten, um eine zur Bildung von regionalen Inlandeisdecken notwendige Temperaturerniedrigung herbeizuführen. Anderseits stellen sich einer ursächlichen Verknüpfung von Eiszeiten mit dem Rückgange der eingestrahlten Sonnenwärme ernste Schwierigkeiten entgegen. Bei einer Intensitätsabnahme der Sonnenstrahlung wäre eine gleichmässige prozentuelle Temperaturerniedrigung an der ganzen Erdoberfläche zu erwarten. Indes finden wir, dass bei erdgeschichtlichen Klimaabkühlungen die Temperaturerniedrigung von den höheren Breiten gegen den Äquator zu abnahm, und im Einklange damit der Gegensatz von Klimazonen schärfer ausgeprägt wurde. Dieses spricht ohne Zweifel zugunsten einer Änderung der von der Erdoberfläche ausgestrahlten Wärmenge im Sinne der Kohlensäurehypothese.[2]

Einen weiteren Fingerzeig gibt uns die Betrachtung des Einflusses des Diluvialklimas auf die Vorgänge der mechanischen Verwitterung. Die allgemeine Verstärkung der Frostwirkungen, die in den diluvialen Blockbildungen zum Ausdrucke kommt, wurde selbstverständlich durch eine bedeutend vermehrte Häufigkeit der Temperaturschwankungen um den Nullpunkt hervorgerufen. Letzteres wäre aber schwer zu erklären, wenn man die diluviale Kälteperiode auf eine Verminderung der eingestrahlten Sonnenwärme zurückführen würde, da in dem Falle bloss eine Temperaturerniedrigung vorausgesetzt werden dürfte. Es kommt jedoch bei der Entstehung von Blockbildungen durch die gesteigerten Frostwirkungen in erster Linie nicht auf die absolute Temperaturerniedrigung sondern auf einen häufigen Wechsel von Auftauen und Wiedergefrieren des Wassers an. Ein solches war aber nur unter der Bedingung möglich, dass zur Diluvialzeit die Durchlässigkeit der Atmosphäre für die Wärmeausstrahlung grösser war, und es erwächst ein gewichtiges Argument zugunsten der Kohlensäurehypothese.[3]

So werden wir auf die Kohlensäurehypothese gewiesen, die in letzter Zeit durch eine scharfe Kritik sowohl vom physikalischen, wie vom geologischen Standpunkte in ein bedenkliches Schwanken geraten ist. Während der Streit von physikalischer Seite sich um die Frage nach dem quantitativen Ergebnis der Wärmeabsorption durch die Kohlensäure bewegt, wird von den Gegnern der Kohlensäurehypothese zu häufig übersehen, dass bei der Absorption der von der Erdoberfläche zurückgestrahlten Wärme neben der atmosphärischen Kohlensäure auch der Wasserdampf zur Geltung kommt. Man kann zugeben, dass Schwankungen des atmosphärischen Kohlensäurege-

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1 Vgl. auch die Bemerkungen von HANN (a. a. O., S. 368).

2 Chamberlin, a. a. O., S. 552-553.

3 v. LOZINSKI, *Die Periglaziale Fazies der mechanischen Verwitterung.* Compte rendu du XI. Congr. Géol. Internat., Stockholm, 1910. S. 1052.

haltes allein einen so grossen Einfluss auf die Wärmeverhältnisse der Erdoberfläche nicht hervorbringen würden, wie es für den erdgeschichtlichen Klimawechsel notwendig erscheint, es wird aber dieser Einfluss durch gleichzeitig und in demselben Sinn erfolgende Änderungen des Wasserdampfgehaltes der Atmosphäre erheblich verstärkt. Da ein Eingehen auf die Kohlensäurehypothese vom physikalischen Standpunkte nicht im Rahmen dieser Betrachtungen liegt, möchte ich die physikalische Grundlage durch die Untersuchungen von EKHOLM[1], die auffallenderweise von den Gegnern der Kohlensäurehypothese nicht gewürdigt werden, als gegeben betrachten und nur die geologische Seite einer Betrachtung unterziehen.

Den schwachen Punkt, an dem die Kohlensäurehypothese vom geologischen Standpunkte zunächst angegriffen wurde, bildete ihre ursprüngliche Verknüpfung mit der vulkanischen Tätigkeit, deren Zu- und Abnahme im Laufe der Erdgeschichte in erster Linie den jeweiligen Kohlensäuregehalt der Atmosphäre bestimmen sollte. Indes hat sich der vermutete Zusammenhang von Kälteperioden mit den Minima der vulkanischen Tätigkeit nicht bestätigt. Für die permische Eiszeit scheint eher das Gegenteil der Fall zu sein[2] und ebensowenig ergibt sich für die Diluvialzeit ein solcher „Tiefstand" der vulkanischen Tätigkeit, wie ihn FRECH voraussetzte.[3] Zu den wenigen, zur Diluvialzeit tätig gewesenen Vulkangebieten, die von FRECH als Ausnahmen bezeichnet wurden, muss man die jüngsten Eruptionsphasen im französischen Zentralplateau (nach GLANGEAUD),[4] in der Eifel, in Siebenbürgen, sowie im Jordantal (nach Blanckenhorn)[5] hinzufügen. Ohne Zweifel wird unsere Kenntnis von diluvialen Vulkanausbrüchen sich in der Zukunft immer mehr erweitern, was insbesondere von Südamerika[6] in grösserem Umfange zu erwarten wäre.

Wenn die Annahme eines wesentlichen Rückganges der vulkanischen Tätigkeit während der Eiszeiten versagt, so erwächst zunächst die Frage, ob dieses gegen die Kohlensäurehypothese spricht. Die Intensität der vulkanischen Tätigkeit, wie sie aus dem Umfange der gleichzeitigen Lavaergüsse beurteilt wird, ist für den jeweiligen Kohlensäuregehalt der Atmosphäre ohne Belang. Kohlensäureexhalationen sind doch keine Begleiterscheinung der vulkanischen Ausbrüche, sondern treten erst als die letzte Phase der ausklingenden Vulkantätigkeit auf. Wie das häufige Auftreten von Säuerlingen im engsten Zusammenhange mit tertiären Vulkanen zeigt, können Kohlensäureexhalationen um einen beträchtlichen Zeitraum die eruptive Vulkantätigkeit überdauern. So ist auch das Auftreten einer vorzeitlichen Lavadecke innerhalb des sedimentären Schichtenverbandes absolut

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[1] EKHOLM, *Über Emission und Absorption der Wärme*, Meterolog. Zeitschr., Jahrg. 19, 1902.

[2] PHILIPPI, *Über einige paläoklim. Probleme usw.*, S. 112-113.

[3] FRECH, *Über das Klima der geolog. Perioden*, N. Jahrb. f. Mineralogie usw., 1908, Bd. II, S. 79.

[4] Geolog. Zentralblatt, Bd. XII, Nr. 1798. Bd. XIII, Nr. 74 ff.

[5] BLANCKENHORN, *Neues zur Geol. Palästinas*, Zeitschr. d. Deutsch. Geol. Ges. Bd. LXII, 1910, S. 459.

[6] NORDENSKJÖLD, *Die Polarwelt*, 1909. S. 107-108.

kein Beweis, dass gleichzeitig der Kohlensäuregehalt der Atmosphäre durch vulkanische Exhalationen bereichert wurde. Da übrigens Kohlensäure-exhalationen im letzten Gefolge der eruptiven Tätigkeit sich über einen langen Zeitabstand erstrecken und keine so rasche Zu- oder Abnahme wie die Vulkanausbrüche aufweisen, möchte ich mit KOKEN[1] annehmen, dass der Zufluss der Kohlensäure aus dem Erdinnern zur Atmosphäre im Laufe der Erdgeschichte weitgehenden Schwankungen nicht unterworfen war.

Dem ständigen Zufluss endogener Kohlensäure ist ein ebenfalls kontinuierlicher Verbrauch der atmosphärischen Kohlensäure bei der Zersetzung der Silikate und Umwandlung in Karbonate gegenüberzustellen. Auch von dem Betrag dieses ständigen Verlustes dürfen wir mit Recht voraussetzen, dass er im Laufe der Erdgeschichte keine wesentlichen Änderungen erfuhr, da das kristalline Grundgebirge während jeder geologischen Periode doch in einem gewissen Umfange entblösst und der Einwirkung der atmosphärischen Kohlensäure zugänglich war. Nur in der präkambrischen Zeit, wo die multanebenden Kontinente zum grössten Teil aus kristallinem Grundgebirge bestanden, konnte der Verlust der Atmosphäre an Kohlensäure einen abnorm hohen Betrag erreichen und es ist möglich, dass dadurch die präkambrischen Vereisungen hervorgerufen wurden.

Abgesehen aber von der präkambrischen Zeit liegt die Annahme am nächsten, dass sowohl der Zufluss endogener Kohlensäure wie der Verbrauch der atmosphärischen Kohlensäure bei der Zersetzung von Silikatgesteinen keine so grossen Änderungen erfuhren, um den Kohlensäuregehalt erheblich zu beeinflussen. Ebenso dürfte auch für die Kohlensäuremenge, die bei der Auflösung von Kalkgesteinen auf der Oberfläche der Festländer zur Umwandlung des einfachkohlensauren Kalkes in Kalkbikarbonat verbraucht wurde, das Freiwerden von Kohlensäure bei der Kalkausscheidung im Meer einen entsprechenden Ersatz geboten haben. Soweit es auf die genannten Faktoren ankommt, haben wir für die Vorzeit mit einem ständigen Kreislauf von Kohlensäure zu rechnen, bei welchem der Kohlensäuregehalt der Atmosphäre nur in beschränkten Grenzen schwanken würde. Anders dagegen steht es mit dem Verlust an atmosphärischer Kohlensäure bei der Kohlenbildung. In jenen Perioden, die durch reichliche Kohlenbildung ausgezeichnet waren, wurden dadurch der Atmosphäre bedeutende Kohlensäuremengen auf die Dauer und ohne Ersatz entzogen. Die Verarmung der Atmosphäre an Kohlensäure im Gefolge einer ausgedehnten Kohlenbildung konnte erst nach längerer Zeit durch den endogenen Zufluss ausgeglichen werden. Ein zeitweise erheblich gesteigerter Zufluss endogener Kohlensäure kommt kaum wahrscheinlich vor. Im vorstehenden wurde bereits betont, dass das quantitative Ergebnis von vulkanischen Kohlensäureexhalationen in keinem Verhältnis zu dem Umfange der Lavaergüsse steht. Danach liegt die Annahme am nächsten, dass der Kohlensäuregehalt der Atmosphäre im Laufe der Vorzeit keine erheblichen Steigerungen über einen gewissen, in engen Grenzen schwankenden Normalwert erfuhr, dagegen zeitweise, wesentlich

[1] KOKEN im Zentralblatt für Mineralogie usw., 1909, S. 539.

unter denselben und zwar im Zusammenhange mit einer ausgedehnten Kohlenbildung herabgedrückt wurde.

In der Tat tritt im Laufe der Erdgeschichte der zeitliche Zusammenhang von Eiszeiten bzw. Kälteperioden mit der Kohlenbildung unverkennbar hervor. Man erkennt es am deutlichsten, wenn man versucht, die Schwankungen der Kohlenbildung (I) und des vorzeitlichen Klimas (II) durch Kurven darzustellen, wie es hier für die Zeit seit dem Karbon unternommen wird. Dass die permische und die quartäre Eiszeit auf Perioden einer

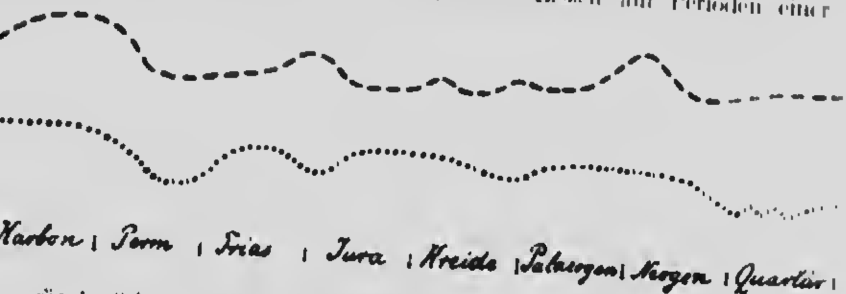

Fig. 1. Schwankungen der Kohlenbildung (I) und des vorzeitlichen Klimas (II).

ausgedehnten Kohlenbildung folgten, ist längst aufgefallen und vielfach erörtert worden. Diese beiden paläoklimatischen Minima fielen jedoch nicht mit dem Höhepunkte der Kohlenbildung zusammen, sondern traten mit einer gewissen Verspätung ein, die am wahrscheinlichsten dadurch zu erklären wäre, dass der Einfluss der Meere, und zwar die Abgabe absorbierter Kohlensäure ihren Verbrauch bei der Kohlenbildung bis zu einer gewissen Grenze kompensieren und dadurch die Abnahme des atmosphärischen Kohlensäuregehaltes verzögern konnte. Wenn auf die oberkarbonisch-unterpermische, sowie auf die mitteltertiäre Periode der reichlichsten Kohlenanhäufung die schärfsten Kälteperioden, d.h. die permische und die quartäre Eiszeit folgten, so wird die Annahme berechtigt, dass die vorzeitlichen Kälteperioden auch in Bezug auf den Grad der Klimaabkühlung und eventuell auf die Ausdehnung der Vereisung von dem Umfange der vorangehenden Kohlenbildung abhängig waren. So waren Kälteperioden, denen Kohlenbildung in beschränkterer Ausdehnung voranging, von keinen oder nur von ...alen Vereisungen begleitet. Bei der Klimaabkühlung an der Wende der ...as- und Jurazeit springt der zeitliche Zusammenhang mit der rhätisch-...erliassischen Periode der Kohlenanhäufung in die Augen. Mit dem ...auffolgenden, fast vollständigen Rückgang der Kohlenbildung fällt eine ...ärmung des Klimas von längerer Dauer zusammen. Die Tatsache, dass ...Bereiche der karpatischen Geosynklinale der mediterrane Faunencharakter ...höheren Jura und in der unteren Kreide sozusagen seinen Höhepunkt ...icht, weist ohne Zweifel auf eine Erweiterung der wärmeren Klimazonen ... Norden hin. Letzteres kommt auch darin zum Ausdrucke, dass um ...Mitte der Jurazeit die regionale Differenzierung der Pflanzenwelt wesentlich abgeschwächt wurde und—wie es GOTHAN betont—vielleicht überhaupt die relativ gleichmässigste Pflanzenverteilung auf der Erde" herrschte.[1] Die Kohlenbildung der Wealdenzeit hat das Klima zwar unmittelbar nicht beeinflusst, möglicherweise aber die oberkretazische Kälteperiode vorbereitet, die im Cenoman einsetzte und gleichzeitig mit der erneuten Kohlenbildung ihren Tiefpunkt am Schlusse der Kreideperiode erreichte.

Wenn wir auf altpaläozoische Zeit zurückgreifen, so lässt sich für die unterdevonische Kälteperiode ein Zusammenhang mit der Kohlenbildung nicht feststellen, abgesehen von der Möglichkeit, dass die Graphitlager der metamorphen Sedimente auf eine vordevonische Periode der Kohlenbildung hindeuten.

Dass die Perioden der Kohlenbildung die darauffolgende Abkühlung bis zu einem gewissen Grade beeinflussen konnten, gab SOLGER zu, wobei er aber annahm, es wäre auch die Kohlenbildung ihrerseits durch eine Klimaabkühlung bedingt.[2] In ähnlicher Weise hat später PHILIPPI Eiszeiten und Kohlenbildung als Folgen einer Abkühlung aufgefasst.[3] Es sei aber darauf hingewiesen, dass die Flora der Steinkohlenzeit noch ein gleichmässig warmes, mindestens subtropisches Klima andeutet,[4] während die Abkühlung erst in der Permzeit erfolgte. Ohne Zweifel war die Periodizität der Kohlenbildung von irgend einer Ursache abhängig, und am nächsten liegt der Gedanke an einen ursächlichen Zusammenhang mit den orographischen Verhältnissen. In diesem Sinne ist ein indirekter Einfluss der diastrophischen Periode auf das Klima der Vorzeit nicht ausgeschlossen.

DIE INTERGLAZIALZEITEN.

Die Vielheit der quartären Eiszeit und die Interglazialzeiten bilden den schwachen Punkt, an dem die meisten Eiszeithypothesen scheiterten. Nur die Kohlensäurehypothese eröffnet uns die Möglichkeit einer ungezwungenen Erklärung der mehrfachen Wiederkehr von „Eiszeiten", wie es zur Quartärzeit der Fall war.

Eine Verknüpfung der Interglazialzeiten mit der Kohlensäurehypothese hat bereits CHAMBERLIN versucht, indem er auf den Umstand hinwies, dass durch die Ausbreitung von Inlandeisdecken grosse Gebiete des Grundgebirges der subaërischen, mit dem Verbrauch der atmosphärischen Kohlensäure verbundenen Zersetzung entzogen wurden.[5] Wie richtig diese Voraussetzung auch ist, do dürften dabei keine so grossen Kohlensäuremengen in Betracht kommen, um das Schwinden einer ausgedehnten Inlandeisdecke und — nachdem der entblösste Untergrund wieder der Zersetzung unter gleichzeitigem Verbrauch der atmosphärischen Kohlensäure zugänglich wurde — die erneute Ausbildung einer Inlandeisdecke zu erklären.

In der Auffassung von CHAMBERLIN erscheint eine Interglazialzeit als

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[1] GOTHAN, *Paläobotanik*. (Handwörterbuch der Naturwissenschaften, Bd. VII), S. 457.

[2] SOLGER, *Die Moore*, Zeitschr. d. Ges. f. Erdkunde zu Berlin, 1905, S. 715-716.

[3] PHILIPPI, *Über einige paläoklim. Probleme usw.* S. 147.

[4] GOTHAN, a. a. O., S. 455.

[5] CHAMBERLIN, *A Group of Hypotheses on Climatic Changes*, Jour. Geol., Vol. V, 1897, p. 682.

eine sozusagen automatische Konsequenz der Vereisung. Wenn wir die Kohlensäurehypothese der Kohlenbildung unterordnen, wie es im vorstehenden Abschnitt versucht wurde, so gelangen wir *a priori* zu der Annahme, dass das Schwinden einer ausgedehnten Eiszeit zugleich Vorbedingungen einer Rekurrenz der Eiszeit schaffen kann. Bekanntlich fällt die geographische Verbreitung der Moorbildung in der Gegenwart zum grössten Teil mit den zur Diluvialzeit eisbedeckten Gebieten zusammen. Nach dem Rückgang einer ausgedehnten Eiszeit bietet der eisverlassene Boden mit unzähligen geschlossenen Becken den günstigsten Raum zur Anhäufung von vegetabilischem Material, wodurch bedeutende Kohlensäuremengen der Atmosphäre entzogen werden. In zweiter Linie kommt auch der Umstand hinzu, dass der vom Eis reichlich ausgebreitete und nachher entblösste Detritus von Kalk- und Silikatgesteinen in erhöhtem Mass der subaërischen Auflösung bzw. Zersetzung zugänglich wird und diese Vorgänge den Verbrauch der atmosphärischen Kohlensäure vermehren. Die Abnahme des Kohlensäuregehaltes der Atmosphäre könnte im Gefolge einer entsprechend grossen, zum Schwinden gelangenden Eiszeit höchstwahrscheinlich ausreichen, um eine neuerliche Vereisung herbeizuführen, die aber jedenfalls in viel engeren Grenzen sich halten würde.

Sollten die obigen Ausführungen für die Wiederholung der diluvialen Eiszeit zutreffen, so müssen wir verlangen, dass erstens die älteste Vereisung den grössten Umfang erreiche, die nachfolgenden dagegen an Ausdehnung immer mehr zurückbleiben und dass zweitens der Wechsel von Eis- und Interglazialzeiten einen allgemeinen Parallelismus aufweise.

Die erste Bedingung trifft nur insofern zu, als die jüngste Vereisung gegenüber der vorletzten Haupteiszeit in der Tat in viel engeren Grenzen sich ausbreitete. Das Auftreten von jüngsten, frischen Moränenbildungen im Innern des Verbreitungsgebietes der entkalkten und zersetzten Ablagerungen der vorletzten (Haupt-) Eiszeit kehrt, sowohl im Bereiche des nordeuropäischen diluvialen Inlandeises wie bei den lokalisierten Gebirgsvergletscherungen, mit solcher Gesetzmässigkeit wieder, dass wir es als eine allgemeine Erscheinung betrachten dürfen. Der Verbrauch der Kohlensäure, auf den die weitverbreitete Zersetzung der Ablagerungen der vorletzten Eiszeit und die Torfbildungen der darauffolgenden Interglazialzeit hinweisen, war gewiss gross genug, um die letzte Rekurrenz der Vereisung herbeizuführen.

Während wir somit für die jüngste Eiszeit mit der Kohlensäurehypothese auskommen können, entsteht eine neue Schwierigkeit dadurch, dass der Haupteiszeit — wie im Gebiete des nordeuropäischen diluvialen Inlandeises — mindestens noch eine älteste Vereisung von kleinerem Umfange vorausging. Wollte man auch in diesem Fall auf dem Boden der Kohlensäurehypothese beharren, so müsste man auf den eingangs erwähnten Standpunkt von CHAMBERLIN zurückkommen.

Das Problem einer Parallelisierung von Eis- und Interglazialzeiten stellt den verwickeltsten und umstrittensten Punkt der Quartärgeologie dar. In dieser Beziehung kommt es vor allem auf die richtige Bewertung von Perioden eines Rückganges der Vereisung an. Von einer echten Interglazialzeit müssen wir verlangen, dass sie—selbstverständlich in grösserer Ausdehnung—durch interglaziale Bildungen sowie durch eine tiefgreifende Verwitterung der Ablagerungen der vorausgehenden Eiszeit angedeutet sei. Diese Bedingung wird von der letzten Interglazialzeit in so weiter Verbreitung erfüllt, dass wir sie mit vollem Recht als eine allgemeine Erscheinung ansprechen dürfen. Im Gegenteil scheinen Interglazialzeiten, die aus einer morphologischen Untersuchung von einzelnen Gebirgsvergletscherungen abgeleitet werden, einen ungleichen Wert zu haben und zum Teil nur längeren, aber doch untergeordneten und lokal beschränkten Rückzugsstadien zu entsprechen. Wie unverlässlich und elastisch die morphologische Betrachtung allein bei der Feststellung von Interglazialzeiten ist, zeigt der Umstand, dass man einerseits die diluviale Vergletscherung der Hohen Tatra, für die aus der Aufeinanderfolge von tiefzersetzten und frischen Moränenbildungen nur zwei Eiszeiten sich ergeben,[1] in das viergliedrige alpine Schema hineinzwingt,[2] anderseits aber den glazialen Formenschatz der Alpen neulich durch eine bloss zweimalige Vergletscherung zu erklären versucht.[3] Wenn wir die interglazialen, pflanzenführenden Ablagerungen der Alpen überblicken, so finden wir, dass sie—mit Ausnahme eines einzigen, wahrscheinlich zur vorletzten Interglazialzeit gehörigen Vorkommens ausschliesslich der letzten Interglazialzeit zufallen.[4] Diese Beschränkung der meisten Interglazialablagerungen auf das Niveau der letzten Interglazialzeit darf keinesfalls in dem Sinne erklärt werden, es seien die Ablagerungen der älteren Interglazialzeiten durch darauffolgende, neuerliche Vergletscherungen vernichtet worden. Sonst wäre es kaum einzusehen, warum nur der allgemeine Gletschervorstoss der jüngsten Eiszeit gegenüber den Ablagerungen der letzten Interglazialzeit sich so rücksichtsvoll erwiesen hätte. Vielmehr müssen wir die zeitliche Verteilung der alpinen Interglazialzeiten als *primär* betrachten und daraus folgern, dass die letzte Interglazialzeit, der die meisten interglazialen Ablagerungen zufallen, gegenüber den älteren Interglazialzeiten der Alpen eine höhere *Bedeutung* besass.

In Bezug auf das Problem der Interglazialzeiten haben wir ebenfalls zwischen regionalen Vereisungen, d. h. Inlandeisdecken und lokalen Gebirgsvergletscherungen zu unterscheiden. Eine regionale Vereisung, die ein grösseres Gebiet umfasst, ist selbstverständlich von schwächeren Klimaoszillationen weniger abhängig und nur weitgehenden Klimaschwankungen unterworfen. Dementsprechend sollen Versuche einer allgemeinen Gliederung der quartären Eiszeit nicht an das alpine Schema anknüpfen, sondern

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[1] PARTSCH, *Die Hohe Tatra zur Eiszeit*, Berichte d. Sächs. Ges. d. Wiss. Phil.-hist. Kl. Bd. LX. 1908.—Ein drittes Schotterniveau, aus welchem PARTSCH (ebda. S. 186) auf die Möglichkeit einer dreifachen Vergletscherung schliesst, stellt in Wirklichkeit eine präglaziale, fluviatile Schotterablagerung dar, die neulich von DE MARTONNE (Bull. de géogr. Histor. et descr. 1911, S. 403) in ihrer weiteren Ausdehnung verfolgt wurde.

[2] LUCERNA, *Glazialgeolog. Unters. d. Liptauer Alpen*, Sitzungsber. d. kais. Akad. d. Wiss. Math.-naturw. Kl. Bd. CXVII (1) Wien, 1908, S. 799-800.

[3] PASSARGE, *Physiologische Morphologie*. Mitteil. d. Geogr. Ges. in Hamburg. Bd. XXVI, 1912. S. 260-261.

[4] PENCK-BRÜCKNER, *Die Alpen im Eiszeitalter*, Bd. III. S. 1157, 1159.

von ehemaligen Inlandeisdecken ausgehen. Angesichts der Divergenz, welche in Bezug auf die Zahl der Interglazialperioden zwischen den Alpen und dem nordeuropäischen Inlandeis sich ergiebt,[1] müssen wir die im Gebiete des letzteren gesicherte Gliederung vorziehen und an zwei Interglazialperioden festhalten. Gebirgsvergletscherungen dagegen, die von einzelnen individualisierten Karmulden genährt werden, sind auch auf untergeordnete Klimaoszillationen empfindlich, die unter Umständen ebenfalls als Interglazialperioden zur Geltung kommen können. Höchst wahrscheinlich wird die Zahl von Interglazialperioden, die eine Gebirgsvergletscherung aufweist, von lokalen geographischen Faktoren beeinflusst.

DER EINFLUSS VON KÄLTEPERIODEN AUF DIE TEMPERATURVERHÄLTNISSE DER MEERESRÄUME.

Bekanntlich rührt die niedrige Temperatur des Tiefenwassers der Ozeane von dem kalten Polarwasser her, das in die Meerestiefen eindringt und dem Einfluss der Sonnenwärme entrückt. Als die erste Kälteperiode in der Erdgeschichte eintrat, wurden die Meerestiefen zum erstenmal mit kaltem Wasser ausgefüllt. Es taucht aber die Frage auf, ob die niedrige Temperatur der Meerestiefen seit der ältesten Kälteperiode *unverändert* bis auf die Gegenwart sich erhält. Zu häufig wird die Meinung geäussert, dass die niedrige Temperatur des ozeanischen Tiefenwassers seit uralter Zeit besteht. Soweit es auf die Sonnenwärme ankommt, für welche die grösseren Tiefen unzugänglich sind, wäre diese Ansicht kaum antastbar, vorausgesetzt natürlich, dass die ozeanischen Becken seit der frühesten Zeit tief genug waren. Es kommt aber die eigene Wärmestrahlung der Erde hinzu, mit der wir zu rechnen haben, sobald längere Zeiträume in Betracht kommen. Genügt doch die von der Erde abgegebene Wärmenenge (jährlich rund 54 Grammkalorien pro 1 cm^2), um vom Meeresboden aus durch Konvektion eine 4000 m hohe Wassersäule in 75000 Jahren um 10° zu erwärmen.

Es wäre kaum anzunehmen, dass in den warmen Perioden der Vorzeit ein vollständiger Ausgleich der Temperatur auf der Erde stattgefunden habe, sodass die zirkumpolaren Gebiete eines „tropischen" Klimas sich erfreuen würden. Andererseits aber unterliegt es keinem Zweifel, dass während der paläoklimatischen Maxima die Temperaturzunahme in höheren geographischen Breiten am grössten war, wodurch die Differenzierung der Klimazonen erheblich abgeschwächt wurde und die zirkumpolaren Gebiete in der Tat ein „milderes", vom heutigen bedeutend wärmeres Klima aufzuweisen hatten. Folglich musste auch die Zufuhr kalten Wassers von den Polargegenden her zu den Meerestiefen zurückgehen und auf längere Zeit hin gänzlich aufhören. Bei der Länge der geologischen Zeiträume dürfen wir mit aller Wahrscheinlichkeit annehmen, dass jeweilig während der vorzeitlichen Wärmeperioden die Temperatur der Meerestiefen durch Konvektion der

[1] WAHNSCHAFFE, *Über die Gliederung der Glazialbildungen Norddeutschlands*, Zeitschr. f. Gletscherkunde, Bd. V, 1911.

Wärmestrahlung der Erde vom Meeresboden aus allmählich um einen namhaften Betrag erhöht wurde. Inwieweit dabei eine „Umkehrung der Wasserzirkulation in Meerestiefen", wie sie CHAMBERLIN verlangt,[1] eintreten und die Durchwärmung des ozeanischen Tiefenwassers beschleunigen konnte, ist schwer zu beurteilen.

Die vorstehende Betrachtung führt zu dem Schluss, dass die Temperaturverhältnisse der Meerestiefen von den Klimaänderungen beeinflusst werden. Während der vorzeitlichen Kälteperioden wurden die Meerestiefen immer wieder mit kaltem Wasser ausgefüllt, wogegen in den dazwischen liegenden Wärmeperioden eine erhebliche Temperaturerhöhung des ozeanischen Tiefenwassers eintreten musste.

Es drängt sich die Frage auf, ob die Abkühlung des Tiefenwassers infolge einer Kälteperiode irgendwelche Spuren in bathyalen Meeresablagerungen hinterlassen kann. Da die Auflösung von kohlensaurem Kalk durch das Meereswasser bei tieferer Temperatur zunimmt,[2] hätten wir vor allem Erscheinungen einer gesteigerten Kalkauflösung zu erwarten. Dazu gehört die einseitige Korrosion oder Zerstörung von Cephalopodenschalen, wie man es in der Fazies der devonischen „Kramenzelkalke"[3] und in der Adneter Fazies des alpinen Lias[4] findet. Merkwürdigerweise fallen diese Ablagerungen des tieferen Meeres in Abkühlungsperioden, die wir auch aus anderen Gründen vorausgesetzt haben. Die Fazies der „Kramenzelkalke" tritt im Unterdevon, also gleichzeitig mit einer Klimaabkühlung auf und reicht bis in das untere Oberdevon hinauf, wodurch angedeutet wäre, dass im Gefolge der unterdevonischen Kälteperiode die niedrige Temperatur der Meerestiefen bis zur jüngeren Devonzeit sich erhalten konnte. Ebenso entsprechen die gleichen Erscheinungen in Liasablagerungen jener Klimaabkühlung, die wir ungefähr an die Grenze der Trias- und Jurazeit setzten.

Der grosse Einfluss, den Klimaänderungen auf den vorzeitlichen Entwicklungsgang der organischen Welt hatten, ist insbesondere von FRECH gewürdigt worden.[5] Dass Bewohner des Landes und auch diejenigen der oberen Wasserschichte der Ozeane, soweit die Wärmestrahlen der Sonne eindringen können, von erdgeschichtlichen Klimaänderungen betroffen wurden, ist ohne weiteres begreiflich. Nun sahen wir aber, dass auch die dem unmittelbaren Einfluss der Sonnenwärme entzogenen Meerestiefen doch säkularen Temperaturänderungen im Gefolge von Klimaschwankungen unterworfen sind, soweit letztere die entsprechende Dauer und Amplitude

[1] CHAMBERLIN, *On a possible reversal of deep-sea circulation*, Jour. Geol., Vol. XIV, 1906.

[2] Vgl. die Ausführungen von PHILIPPI, Deutsche Südpolar-Expedition, 1901–03, Bd. II, S. 608.

[3] FRECH, *Die Karnischen Alpen*, Halle 1894, S. 288-290.

[4] WÄHNER, *Zur heteropischen Differenzierung des alpinen Lias*, Verhandl. d. k. k. Geolog. Reichsanstalt, 1886, S. 191.

[5] FRECH, *Über die Gründe des Aussterbens der vorzeitlichen Tierwelt*, Archiv für Rassen- und Gesellschafts-Biologie, Jahrg. III, 1906.

Geolog. *Triebkräfte und die Entwicklung des Lebens*, ebda. Jahrg. VI, 1909.

erreichen. Es hat Abel auf die Bedeutung der Temperaturerniedrigung des ozeanischen Tiefenwassers infolge von Kälteperioden für die Umprägung der Tiefseefauna hingewiesen.[1]

Wenn von dem Einfluss der erdgeschichtlichen Temperaturänderungen der Meerestiefen auf die Entwicklung ihrer Fauna die Rede ist, so kommt auch in Betracht die Geschwindigkeit, mit welcher eine Abkühlung bzw. Erwärmung des ozeanischen Tiefenwassers infolge einer Klimaänderung sich vollziehen kann. Aus der eingangs beispielsweise angeführten Berechnung müssen wir annehmen, dass eine Erwärmung der abgekühlten Meerestiefen durch die Wärmestrahlung der Erde äusserst langsam erfolgt und somit einen viel längeren Zeitraum erfordert, als der umgekehrte Vorgang, d. h. eine Abkühlung der ozeanischen Tiefen durch das eindringende Polarwasser beim Eintritt einer Kälteperiode. Von einschneidender Bedeutung für die Organismen der Meerestiefen kann nur eine Abkühlung sein, die im Zusammenhang mit Kälteperioden in relativ kurzer Zeit sich vollzieht. Bei einer Erwärmung der Meerestiefen dagegen, die während einer Wärmeperiode durch die Wärmestrahlung der Erde äusserst langsam und allmählig erfolgt, erscheint ein weitgehender Einfluss auf die Entwicklung der Organismen kaum möglich. So ist auch eine derartige Erwärmung eines Meeresbeckens in relativ kurzer Zeit, wie sie von Noetling für das „plötzliche Aussterben" der jungpaläozoischen Brachiopodenfauna angenommen wird,[2] nicht denkbar.

Inwieweit das Tiefenwasser eines ozeanischen Beckens in niederen geographischen Breiten durch das Polarwasser während einer Kälteperiode abgekühlt wurde, hing auch von der morphologischen Gestaltung des Meeresbodens ab. Ein Meeresbecken, das durch genug hohe submarine Rücken abgeschlossen war, konnte dadurch vor dem Eindringen des kalten Wassers aus zirkumpolaren Gebieten mehr oder weniger geschützt werden. Dafür bietet in der Gegenwart das Mittelländische Meer ein allgemein bekanntes Beispiel. In einem derart abgeschlossenen Meeresbecken in niederen geographischen Breiten konnte der Einfluss von Kälteperioden erheblich abgeschwächt bzw. verzögert werden.

Die Entwicklungsgeschichte der marinen Organismen zeigt, dass in der Vorzeit sog. Umprägungsperioden, die oft mit einer „explosiven Entwicklung" neuer Arten verbunden waren, mit langen Perioden einer äusserst ruhigen Entwicklung abwechselten. Das Zusammenfallen der Umprägungsperioden mit einer Abkühlung des Klimas bzw. mit Eiszeiten, wie am Schlusse der paläozoischen und der mesozoischen Ära, erklärt sich durch die allgemein bekannte Tatsache, dass kälteres Meerwasser reicher an Sauerstoff und Plankton ist.[3] Indem die in relativ kurzer Zeit erfolgende Abkühlung der Meeresräume beim Hereinbrechen einer Kälteperiode die wenig wider-

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[1] Abel, *Die Anpassungsformen der Wirbeltiere an das Meeresleben*, Schriften d. Ver. z. Verbr. naturw. Kenntn. in Wien, Bd. XLVIII, 1907-8, S. 419.

[2] *Lethaea geognostica* (Trias), S. 530.

[3] Vgl. auch die trefflichen Bemerkungen von Philippi, *Über das Problem der Schichtung*, Zeitschr. d. Deutsch. Geolog. Ges., Bd. LX, 1908, S. 359.

standsfähigen Organismen vernichtete, wurde zugleich durch die reichlichere Nahrungsproduktion im kälteren Wasser ein rasches, buchstäblich „explosives" Aufblühen und Ausbreiten von anpassungsfähigen Tiergruppen begünstigt. Während der Wärmeperioden dagegen musste, infolge einer langsam fortschreitenden Erwärmung der ozeanischen Becken, die Menge des Sauerstoffs und des Planktons, somit auch die Nahrungsproduktion im Meerwasser zurückgehen, sodass an Stelle der jähen Umprägungsperioden eine äusserst ruhige und langsame Umbildung der Meeresfauna trat.

FIELDS OF OUTFLOW OF THE NORTH AMERICAN ICE-SHEET.

BY

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Glacialists are indebted to the late Dr. GEORGE M. DAWSON of the Geological Survey of Canada, for the earliest recognition, published in the years 1886 to 1890, of two central areas upon which the North American ice-sheet was accumulated in greater depth than elsewhere, and from which, consequently, it flowed outward on all sides.

One of these areas embraced the Laurentide highlands, James bay, a portion of Hudson bay, and the western part of the Archæan region from Lakes Superior and Winnipeg to Great Slave and Great Bear lakes. From this large northeastern or Laurentide centre of outflow the ice-sheet crept southward, eastward and northward to the limits of glaciation. Westward, the ice from this area outflowed to the limit of Archæan boulders at or near the base of the Rocky mountains, where I find, from Dr. DAWSON's observations of the drift in Alberta and on Peace river, that it abutted against and was confluent with ice flowing eastward and southeastward from the Rocky mountains. The other area whence currents of the ice-sheet flowed radially in every direction was the north-central part of British Columbia.

The portions of the ice-sheet pouring outward from these two centres were named, respectively, by DAWSON the Laurentide and Cordilleran outflow glaciers. Toward the south, west and northwest, the Cordilleran outflow extended to the boundaries of our glaciated area; but, pouring eastward through passes in the Rocky mountains, and in the Peace River region probably over-topping the highest summits, which are only about 6,000 feet above the sea, the Cordilleran ice pushed across a narrow belt adjoining the mountains to a maximum distance of nearly 100 miles, and there (on land about 2,500 feet above the sea) became confluent with the Laurentide ice. The two united currents thence passed southward and northward from the interior tract where the confluent ice was thickest.

In 1896 I published a small map of North America, showing these grand divisions of its glaciation.[1] This is also used, with delineations of the surface areas of the Kansan, Illinoian, Iowan, and Wisconsin drift-sheets, by LEVERETT.[2]

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[1] *The Glacial Lake Agassiz*, U.S.G.S. Mon. XXV, (1896).
[2] *The Illinois Glacial Lobe*, U.S.G.S. Mon. XXXVIII, (1899).

The discrimination of two chief areas of ice accumulation and outflow within the great expanse of the Laurentide glacier east of the Rocky mountains, since named the Keewatin and Labrador areas of glaciation, was suggested by Mr. J. B. TYRRELL from his observations on the west side of Hudson bay, Lake Athabasca, and Churchill river. This was first shown by CHAMBERLIN in 1894 on a map of the North American ice-sheet, which forms the frontispiece to the chapters he contributed to the largely rewritten third edition of Prof. JAMES GEIKIE'S admirable work, *The Great Ice Age*. This little map, with some modifications and additions of the names of the Cordilleran, Keewatin and Labrador ice-sheets, which are merged into one continent-wide mer de glace, is reprinted in CHAMBERLIN and SALISBURY'S *Geology* (1906, Vol. III, p. 329).

Keewatin, the Algonquin word for the northwest wind, was the name applied to a former governmental district of Canada, lying west of James and Hudson bays and extending north to the Arctic sea. This district, under the present civil divisions of Canada, forms parts of Ontario, Manitoba, and the North West Territories.

The name Labrador, as here used, refers evidently to the great peninsula bounded by the Labrador coast of the Atlantic ocean on the east, by the Gulf of St. Lawrence on the southeast, and by Hudson strait and Hudson and James bays on the north and west. Labrador proper, however, as the name was originally used and is now governmentally restricted, comprises only a limited northeastern tract of this peninsula.

Professor CHAMBERLIN wrote of these central and eastern areas of our continental ice-sheet, as follows:[1]

"Perhaps the most plausible hypothesis at present is that glaciation on the American mainland set in independently in Labrador and in the region northwest of Hudson bay, perhaps in more than one locality, and that these nuclei grew until their borders coalesced, submerging the Hudson Bay region, and at length developing a great arcuate zone of accumulation along the Laurentian uplands from the coast of Labrador all the way round to the Arctic ocean, embracing at the maximum of glaciation a great reservoir of ice, as Dr. Bell has expressed it, in the Hudson basin. It is possible that the ice over this central basin grew to be a central embossment, but there is no evidence that it was ever so dominant as to cause the ice to push eastward over the Labrador plateau. An arcuate zone of accumulation, in a more restricted sense, has been a favourite conception of some American glacialists; but is doubtful whether it could have originated as such, and the conception cannot be pushed very far in view of the abundant evidence of transportation from Hudson bay south-southwesterly across the Laurentian tract, but not in the opposite direction.

"There seems no present ground for believing that the Laurentian uplands between Hudson bay and Lake Superior were even gathering grounds of such dominance as to produce a northerly movement of the ice."

[1] *The Great Ice Age*, 1894, pp. 733-4.

The views thus stated seem accordant with all that is known of the glacial drift in the United States and Canada, except that the west side of the Keewatin glaciation was doubtless confluent with Cordilleran glaciation from the contiguous Rocky mountains, as is shown in the reprint of the map, and with the further exception of the Patrician glacier, made known by Mr. TYRRELL's paper in the present session of this Congress.

During the maximum stages of the continental ice-sheet in the Mississippi basin the southernmost part of the Keewatin glaciation spread the Kansan drift, and the most southwestern extension of the Labradorean ice-fields brought the Illinoian drift. These diverse drift-sheets have been regarded as considerably different in age, because at Yarmouth and elsewhere in southeastern Iowa a part of the Kansan till is overlain by the edge of the Illinoian till, with intervening deposits of stratified sand and clay and peat beds. But it seems to me more probable that the Kansan and Illinoian drift-sheets are in general of synchronous deposition and represent respectively the contemporaneous greatest extensions of ice accumulation and outflow from these central and eastern areas of continental glaciation.

The belt of confluence of the southern parts of the Keewatin and Labradorean ice-fields, characterized here and there by overlapping, interstratification, and intermingling of the drift brought from the northwest and north with that brought from the northeast, extends along or near the Mississippi river from the southern borders of the drift up to the large driftless area of southwestern Wisconsin. Beyond the driftless area, this line or belt of confluent ice-fields stretches north-northwestward through Minnesota to the vicinity of Winnipeg in Manitoba and onward along the axis of Lake Winnipeg.

I have described[1] remarkable deposits of interbedded and confusedly mingled till and modified drift of Wisconsin age in this belt at and near Minneapolis, which came from the northwest and the northeast. The former are marked by bluish colour at considerable depths but superficially are yellowish gray through weathering, with plentiful limestone boulders and pebbles. The latter are predominantly reddish and contain little or no limestone.

In the city of St. Paul, for three miles from the state capitol northwest to Lake Como, the latest minor fluctuation of the line of glacial confluence caused the reddish till from the northeast, varying from one or two feet in thickness to five feet or more, to lap over yellowish modified drift filled with limestone pebbles that came from the northwest. This overlap can be observed over a width of a half-mile or more.

An opposite and much greater overlap that brought the Keewatin ice upon a large tract previously occupied by the Labradorean ice during the Wisconsin stages of general wane of glaciation, is observed in many sections within the next 40 or 50 miles north from St. Paul and Minneapolis. The ice flowing from the west extended its former limits eastward across Wright, Hennepin, Anoka and Sherburne counties of Minnesota, to St.

[1] Am. Geologist, Vol. XXV, May, 1900, pp. 273-299, with a map and sections

Croix river, and into the adjoining edge of Wisconsin, pushing back the ice current that came from Lake Superior, and covering the red till brought by that ice with the characteristic bluish gray till from the northwest and west.

This change in the course of the line along which the currents of the west and east portions of the ice-sheet met is due to the changed meteorological conditions of this time. During the increased ice-melting attendant upon the recession of the ice-fields, the prevailing westerly winds, as they swept over the western side of the ice-sheet upon the Coteau des Prairies and eastward, became more laden with moisture than in the earlier part of this Wisconsin stage, when there was comparatively little melting on the surface of the ice; and the increased temperature enabled these winds to carry their moisture farther than when the ice had its greater extent. During this earlier period rain and snow were precipitated more upon the western side of the ice; but later, by reason of the causes here mentioned, the precipitation probably became much greater on the east part of the lobe of the ice-sheet that extended southeastward from the Red River valley to central Iowa. Before this, Lake Minnetonka and central Wright county had been the limit where this ice-flow was stopped by the opposing ice-current from Lake Superior; but now, because of the relatively and perhaps absolutely greater thickness of this part of the ice flowing from the northwest, its current pushed back that which opposed it on the east and covered the red till brought by that ice with blue till containing abundant limestone boulders.

The line where these Keewatin and Labradorean ice-fields moving from the west and from the northeast now met, lies in the southern part of Mille Lacs, Kanabec and Pine counties, Minnesota, and even beyond the St Croix river at the east side of Chisago county, fully 75 miles east of the line where they formerly met. But it scarcely reaches into Washington and Ramsey counties, showing that these counties remained covered with ice that came from the northeast. This persistence of the ice-flow from the northeast near the margin of the area that was ice-covered at that time—and also in Stearns and Morrison counties, to the north of the changed portion of the line of glacial confluence as is proved by the character of the drift in these counties, seems quite consistent with the explanation by meteorological agencies of the change in source of the ice that covered the intervening district, from Wright and Hennepin counties eastward to the St. Croix river and the edge of Wisconsin.

Great changes of glacial currents during the closing Wisconsin stages of the Ice Age are known by the overlapping, interdeposition and sometimes confused mingling of the Keewatin and Labradorean drift formations, as here described for considerable tracts in Minnesota. In other areas of the moraine-bearing till-sheets of Wisconsin age, equally remarkable changes of the glacial boundary and of ice-currents are proved by discordant and intersecting courses of the moraine belts. All these changes of glacial currents and interbedding or discordance of drift deposits imply probably no extensive withdrawal and re-advance of the ice front, such as may be properly accepted as evidences of a noteworthy inter-Glacial stage.

In the far longer part of the Ice Age, which comprises the Nebraskan, Kansan, and Illinoian stages of ice accumulation and erosion, transportation, and deposition of drift, and also the intervening Aftonian and Yarmouth stages of retreat of the ice boundaries, we cannot doubt that similarly extensive changes of the glacial currents and of the limits or the belts of confluence of the Keewatin and Labrador ice-sheets took place. South of the Wisconsin driftless area glacial deposits occupy a breadth of nearly 200 miles, where all the land was enveloped at some time, and mostly at two or more times successively, by one or the other of the ice-fields that flowed respectively from the northwest and the northeast, or alternately by each of these ice-fields.

The stages during which the great expanse between that driftless area and the southern margin of the drift sheets, were enveloped in ice were so long—probably 50,000 to 75,000 years in the Nebraskan stage and probably equally long in the Kansan and Illinoian stages of glaciation,—that we may readily believe much fluctuation in the limits of glaciation from the northwest and the northeast to have occurred on that expanse, or in the confluent belt of these ice-currents.

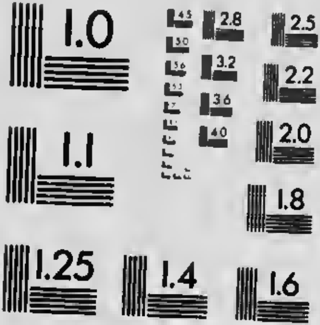
During the mild Aftonian inter-Glacial stage, perhaps 10,000 or 15,000 years or more in length, all that region was relinquished by the ice-sheet. Again in the Yarmouth interval, from an early part of the Kansan drift deposition to the maximum extension of the overlying Illinoian drift in southeastern Iowa, an interglacial land surface may have been exposed locally through 10,000 years, or perhaps four or five times as long, while the greater part of this expanse between the Wisconsin driftless area and the glacial drift border remained enveloped in ice. Indeed, we may attribute to the Kansan and Illinoian stages a contemporaneous continuance of 75,000 years, more or less, ending some 50,000 or 40,000 years ago. Minor oscillations of their glacial boundaries, or of their confluence, may have allowed the Yarmouth interglacial beds to be overridden by the margin of the Illinois glacial lobe only half as long ago as the time of the Kansan drift deposition there, as CALVIN estimated the relative ages of the Kansan and Illinoian drift-sheets in that vicinity.

The entire time of glaciation of our continent, or the aggregate duration of its Glacial stages, probably far exceeded the aggregate duration of its inter-Glacial stages. I believe that, during some important or well defined stages of peripheral deglaciation of the drift area, even for hundreds of miles back from the drift boundary, an unmelted central part of the continental ice-sheet continuously covered a great interior region. However interrupted the processes of glacial erosion of the land surface and transportation of the drift may have been near the margin of our continental area of glaciation, its central portion was subjected to more continuous ice-action, perhaps an almost unbroken period of drift erosion and transportation during nearly all the Ice Age.

That this age in North America was very long, as measured in thousands of years, is proved by the glacial transportation of rock fragments from beds

MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No. 2)



of a peculiar formation on the southeast shore of Hudson bay, where it narrows to form James bay. This rock has been carried for fully 1,000 miles southwest to North Dakota and to the west side of the Wisconsin driftless area.[1] Granting that the rate of motion of the basal part of the ice-sheet bearing these boulders and rock fragments may have averaged 100 feet yearly, which seems a liberal estimate even for its peripheral tracts, we see that 50,000 years would be required for the journey from Hudson and James bays to Steele county, Minnesota. More probably the average annual progress of the drift through this long distance, during which the ice boundaries were far in advance of these slower moving drift fragments, would be not more than a half or a third of the above estimate, and thus 100,000 or 150,000 years would be required.

It is also noteworthy that in the latter part of this journey, a Labradorean ice-current invaded far into the area of predominant Keewatin glaciation, and in consequence a meagre admixture of Labradorean drift was borne far southward on the Keewatin side of the driftless area.

TYRRELL[2] has argued that the Cordilleran glaciation attained its greatest extent earliest; that the Keewatin ice-field next spread to its farthest limits; and that these parts of the continental ice-sheet had successively far withdrawn, or perhaps nearly disappeared, when the greater Labradorean ice-field, in its turn, grew outward in all directions from a nucleus east of Hudson bay and covered the eastern half of our glaciated territory. The greater part of New England, and the provinces of New Brunswick and Nova Scotia, as well as Newfoundland, are mapped by TYRRELL as outside the Labradorean ice-sheet and are evidently regarded as belonging to other, and presumably later, fields of snow and ice accumulation and outflow.

Against this view, which is partly presented again by Mr. TYRRELL in pages 389-391 of a publication in 1910 of the Eleventh International Geological Congress, I must cite the outermost and very old Jerseyan drift, in New Jersey and Pennsylvania, probably contemporaneous with the oldest recognized Nebraskan drift-sheet in the Mississippi basin, which extends south beneath the Aftonian inter-Glacial beds nearly to the maximum limit of glaciation there. In the next great subdivision of the Glacial period I regard the Kansan and Illinoian drift-sheets,—the former on the southern part of the broad Keewatin area, and the latter on the southwestern border of the Labradorean glaciation,—as essentially contemporaneous and produced respectively by the farthest southward development of these vast divisions of our continental ice-sheet.

During the later Iowan and Wisconsin stages of the ice-sheet, when the formerly much elevated land sank beneath its ice-burden and a temperate climate was restored at the margin of the ice, causing it to be melted rapidly, loess was spread in great abundance in the Missouri, Mississippi, and Ohio basins. This implies similar conditions within both the Keewatin and Labradorean areas of glaciation. Also the well developed marginal mo-

[1] U.S.G.S., Mon. XXV, p. 131.

[2] Jour. Geol., Vol. IV, 1896, pp. 811-815; ibid, Vol. VI, 1898, pp. 147-160, with maps.

raines of Wisconsin age, that mark the boundaries of the waning ice-fields, were amassed in a continuous and contemporaneous series from the Atlantic coast at Nantucket and Cape Cod, westerly by Long Island, through northern New Jersey, Pennsylvania, southern New York, Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, and the Dakotas, into Manitoba, Saskatchewan, and Alberta. Distributed across the southern border of New England and of the western extension of the Labradorean glaciation, and through a vast extent of the Keewatin drift area, these moraines demonstrate that the closing stage of the Glacial period witnessed contemporaneous and intensely active drift deposition over fully two-thirds of the width of our continent. Farther west, too, the latest extensive Cordilleran glaciation, including local alpine glaciers south of the continental ice-fields, appears to be correlative and synchronous with the late Wisconsin stage of all the drift region east of the Rocky mountains.

It is thus evident that throughout the Ice Age the ice-fields of the far west, central and eastern parts of North America, were contemporaneously expanded to nearly the full limits of our continent-wide drift-bearing area.

We cannot reliably picture how the accumulations of snow and ice began to form the great North American mer de glace. Probably it grew from several central areas of relatively abundant snowfall, until a very long period of continental glaciation ensued, continuous from the Atlantic to the Pacific.

We can discern more clearly, by the courses of striation and travel of drift boulders, in what directions the ice-borders finally receded, because everywhere the latest, the most distinct, and usually the most plentiful striation was directed perpendicular to the more or less irregularly indented and lobate boundaries of the departing ice-fields. The currents of the latest striation upon the axial tract of the great Labradorean area moved southwesterly for 1,500 miles from western Illinois, Wisconsin, and northeastern Minnesota, across Ontario and Quebec to the plateau and mountains of Labrador because the climatic conditions that melted away the ice-sheet upon that great region acted progressively from west to east, thus sweeping back the ice boundary over nearly half the width of the continent. The southwestern glacial currents and striations in the Mississippi basin long antedated those on the Laurentide highlands and in Labrador. Probably no drift transportation can be traced from Labrador (the coastal region adjoining the Atlantic north of Newfoundland) very far westward.

Professor G. F. Wright has found boulders of red jasper conglomerate near Cincinnati in the north edge of Kentucky, where they were deposited after a glacial journey of about 500 miles nearly due south from their parent ledges north of Lake Huron and about the mouth of Lake Superior. In Vermont, New Hampshire, and Maine, Professor C. H. Hitchcock finds that the glacial currents passed southeasterly across the highest mountain peaks.

Looking broadly on the southern outline of the continental ice-sheet, we see that, east from the Mississippi river and the Wisconsin driftless area, it is indented by a wide embayment that has its apex in southwestern New York. West of that great re-entrant angle of the ice-border was a field of glacial outflow as shown by its axial transportation of the boulders noted by Wright south of Ohio river. This I would name the *Ontario ice-field*, from the Canadian province where it gathered on the north.

East from its great angle the ice-front turned again southward, passing through northeastern Pennsylvania, across New Jersey, and along the axis of Long Island to Martha's Vineyard and Nantucket, in a massive loop which continued beneath the present sea-level, running probably northeast and north to near the southeast corner of Maine. This was the front of the *Quebec ice-field* as it may be named from the province of Quebec, its great northern gathering ground. Its drift was borne southeast across the mountains of New England.

Yet farther east an ice field of similar outline but less area covered New Brunswick, Nova Scotia, and Cape Breton and Prince Edward islands. This may be named the *Nova Scotia ice-field*.

Much of the Gulf of St. Lawrence was probably outside the lobate boundaries of the ice-sheet in its maximum extent, as is indicated by the unglaciated Magdalen islands.

Newfoundland appears to have been independently glaciated, having had only a narrow glacial isthmus of connection northward with our continental ice-sheet.

These several southern fields of glacial outflow, excepting the independent *Newfoundland ice-field*, were appendages of the great Labradorean area of glaciation, which it seems desirable to retain in our general view of the glacial history, as its verity is vindicated by the actual transportation of drift from the east coast of Hudson and James bays for a thousand miles southwestward.

DISCUSSION.

J. W. EVANS (London) remarked on the fact that Dr. Upham had postulated a velocity of from one-third to one-half of a hundred feet per annum for the materials transported by an ice-sheet. The speaker had calculated that the velocity of an ice-sheet 1,000 feet thick with a slope of 1° at a height of one foot above the base would be at the rate of .000,6 of a foot per diem or about one-fifth of a foot per annum (*The Wearing Down of the Rocks*; Proc. Geol. Assoc., Vol. XXIV, 1913, p. 277). The velocity is roughly proportional to the depth of the ice, the slope of the surface and the height of the material transported above the glacier floor. It follows that the velocity referred to by Dr. Upham would require the material to be transported at a considerable height above the base if any reasonable values for the thickness and slope of the ice were assumed.

THE PATRICIAN GLACIER SOUTH OF HUDSON BAY

BY

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About a quarter of a century ago glacialists considered that all the northern portion of North America east of the Rocky mountains, including the basin of Hudson bay, had been covered during the Glacial period by one vast sheet of ice. Dr. G. M. Dawson, late Director of the Geological Survey of Canada, applied the name Laurentide glacier to this great ice-sheet, and a little later, the name "Cordilleran" glacier was applied to the ice-sheet which more or less completely covered the Rocky mountains.

In 1894, after having spent ten years in the country southwest and west of Hudson bay and east of the Rocky mountains and the great valley of Mackenzie river, I indicated for the first time the existence and position of a glacial centre, or gathering ground for ice, in northern Canada, from which the ice radiated outwards to all points of the compass.[1] In 1895, after having spent another summer in the far northern portion of Canada, I applied the name[2] Keewatin glacier to the great ice-sheet which had its centre west of Hudson bay, and which, at its greatest extension, spread over such a vast area of the interior portion of the American continent.

In other[3] papers published at a somewhat later date I showed that the eastern portion of Canada was not covered at any one time by a single great outward-moving ice-sheet, but that the ice of the Glacial period east of the Rocky mountains had had at least two gathering grounds or centres of dispersion. One of these, lying west of Hudson bay and within the country then known as the District of Keewatin, I had called the Keewatin centre of glaciation. For the other, which probably had its centre in Labrador, I proposed to continue to use Dr. Dawson's name of Laurentide glacier, restricting it to the glacier which had its gathering ground in Labrador and

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[1] J. B. Tyrell. *Notes on the Pleistocene of the North-west Territories of Canada*, Geol. Mag., Sept., 1894, pp. 394-399, and map.

[2] J. B. Tyrrell, *A Second Expedition through the Barren Grounds of Northern Canada*, Geog. Journal, Vol. VI, 1895, p. 439. London.

[3] J. B. Tyrell, *The Genesis of Lake Agassiz*, Jour. Geol., Vol. IV, 1896, pp. 811-815.

——*The Glaciation of North Central Canada*, Jour. of Geol., Vol. VI, 1898, pp. 147-160.

——*Report on the Country between Athabasca Lake and Churchill River*, Geol. Sur. Can., Vol. VIII, Part G, 1895.

——*Report on Dubawnt, Kazan and Ferguson Rivers*, Geol. Sur. Can., Vol., IX Part F, 1896.

which radiated outwards from a centre somewhere in that vast peninsula, but as Dr. DAWSON, who was then my superior officer in the Geological Survey, objected to this restriction of his name, I used the term Labradorean glacier instead. This made three great areas of ice accumulation and dispersion in the northern portion of North America, namely, the Cordilleran in British Columbia, the Keewatin in the country west of Hudson bay, and the Labradorean in the country east of Hudson bay.

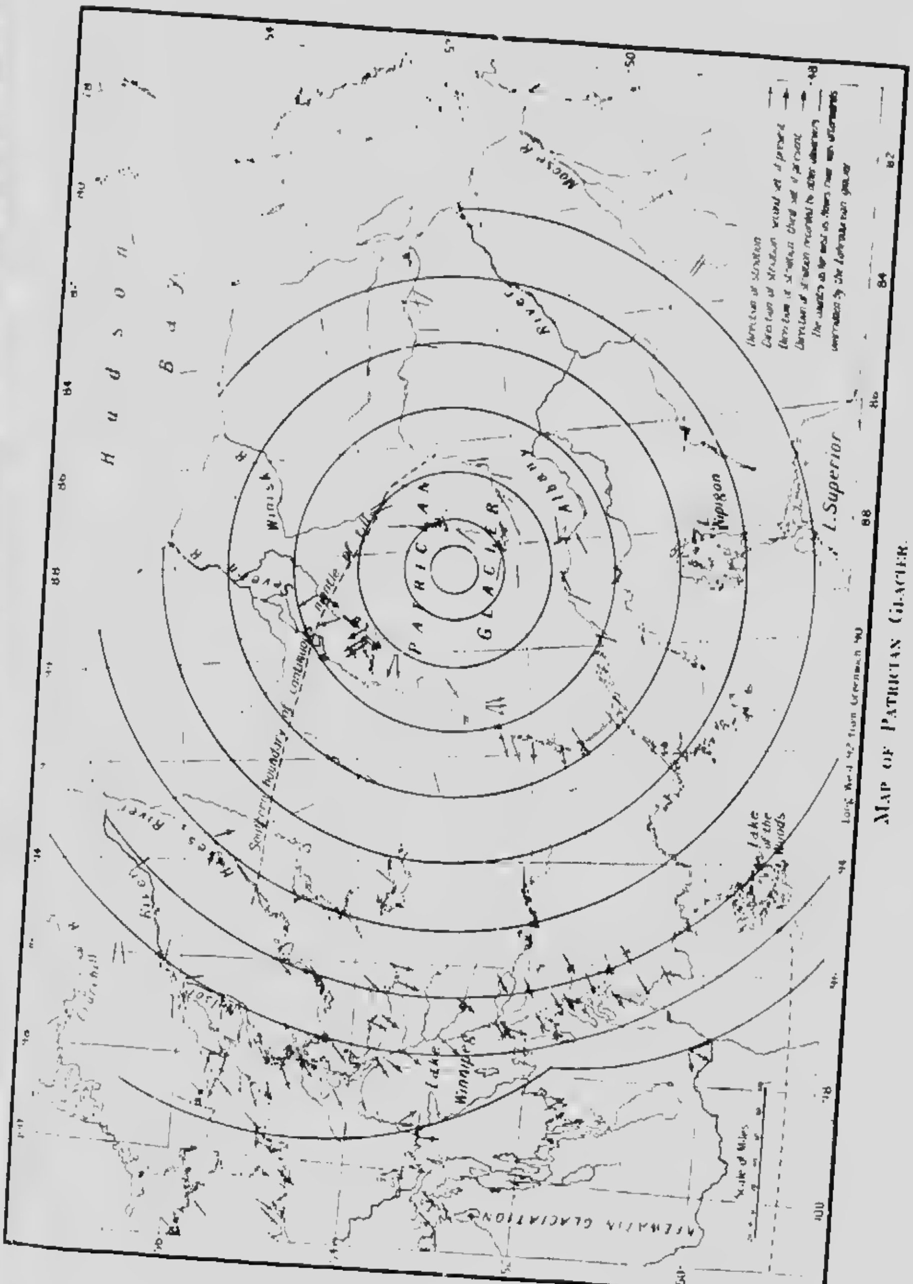
While making these sub-divisions, I distinctly remember having suggested, though I cannot recall having put the suggestion on record, that quite possibly there had been another centre of glaciation south of Hudson bay, but that nothing was yet known of it.

From that time until last summer I had no opportunity of revisiting Hudson Bay or of extending my observations of more than fifteen years ago.

Last summer, however, I descended the Nelson and Hayes rivers to York Factory, situated on the west shore of Hudson bay, in N. Lat. 57°, acting in the capacity of Commissioner for the Government of the Province of Ontario to choose and define certain lands which had been allotted to it by the Dominion of Canada. After having fulfilled this duty, my course took me eastward along the shore of Hudson bay for 240 miles, then southward up Severn river and across the Height of Land to Albany river. This river was travelled for 100 miles or more until the head waters of Winnipeg river were reached, and then these waters were followed to the Transcontinental railway at Graham or Sioux-Lookout. The total distance covered in canoes and boats on the homeward journey from York Factory, was about 1,000 miles and a considerable part of this was over routes previously unexplored. My duties were not those of a geologist but, nevertheless, it was impossible for me to close my eyes to the geological conditions and phenomena which presented themselves day after day. It is now my intention to briefly enumerate some of these conditions.

On the whole the country is low-lying. The number of hills which rise more than 100 feet above the general level is comparatively few and most of these are well-known land marks with distinctive names. The highest of them, known as "The Hill," or Chacutinow, and situated near the banks of Hayes river, was found to have an elevation of 465 feet above the river at its base, or 950 feet above the sea.

While the country is flat-lying and without prominent elevations, it has a fairly regular rise for several hundred miles southward from Hudson bay; south of which it flattens or descends to some extent as it reaches the region of the Great Lakes. The southern portion of this country south of the Height of Land is exceedingly rocky. In many places hardly a trace of soil has been left on it, and such vegetation as is able to grow on it—chiefly spruce and banksian pine—sends its roots down into the cracks in the rock, and thus appears to be growing directly out of the bare smooth rock itself. The hollows between the rocky knolls are partly filled with sand and boulders. Where sand and boulders are absent, the hollows are filled with water, thus forming the lakes which are found in almost countless numbers



MAP OF PATRICIAN GLACIER.

in that northern country. The rock is rounded into roche moutonné surfaces, but these surfaces are usually weathered, so that the direction of motion of the ice during the Glacial period could not be determined except from the contours of the hills. As will be seen later, however, the shapes of the hills are not always safe guides for determining the direction of movement of the ice. Little or no clay can be seen anywhere in this rocky country. A few sand plains and sand ridges may be seen here and there where streams flowed southward from the face of the glacier that advanced from the north, and deposited their burden of sand where they were able to spread out over the rocky ground; but no extensive extraglacial lakes were formed in which the finer and more clayey sediments could settle.

North of this higher and more rocky country, lies the gentle northward slope towards Hudson bay. In travelling down the regular canoe-route from Lake Winnipeg towards Hudson bay the greatest height attained is on Lake Winnipeg itself, at an elevation of 710 feet above the sea, and the slope from that lake to the salt water of Hudson bay is fairly regular throughout. But east of Lake Winnipeg the land is considerably higher, for the watershed between the Albany and Severn rivers has an elevation of 1,470 feet above the sea, while hills in the vicinity are from 100 to 200 feet higher. This elevation, being at the source of rivers flowing northward, eastward and southward, is perhaps the highest ground in the whole district of Patricia. North of it the land is much more attractive in character than that to the south of it, and there are considerable areas where the underlying rock is overlain by good clay loam or sandy till carrying but few boulders. Such country extends down to an elevation of about 600 feet above sea-level while below that level it becomes more generally and evenly covered with a great sheet of till from 10 to 100 feet in thickness. At a somewhat lower level this till is overspread by marine beds of sand or clay, or of both.

The rock underlying most of the higher country is a reddish gneiss, but here and there are longitudinal areas, often of considerable extent, underlain by green diabases, gabbros and basalts, which for the most part would seem to be of Keewatin age.

As the shore of Hudson bay is approached, limestones of Ordovician and Silurian age lying in a nearly horizontal attitude are met. I had the pleasure of making two nice collections of fossils from these limestones last summer, one from the Ordovician limestones of Shamattawa river, and the other from the Silurian limestones of Severn river. As might be expected from the remoteness of these areas from other known outcrops of similar rock, many of the species of fossils were new.

The limestones are hidden everywhere except in the valleys by a covering of clay or till.

I was very much pleased to have the opportunity of seeing this country because other travellers who had passed through adjoining areas had reported that during Glacial time it had been covered by a vast field of ice, and that this ice had persistently moved southwestward, probably from a centre in Labrador, and consequently across a portion of Hudson bay before it had reached this region. The ice had therefore definitely travelled up a regular slope from the Bay. As the highest of the marine deposits, which were formed immediately after the retreat of the ice, have an elevation at present of about 400 feet above the present sea-level, and as these deposits were formed at or below sea-level, the bottom of the glacier itself was in all probability at that time below sea-level, and the glacier was therefore to a certain extent being buoyed up by the water which was beside and around it. The journey, therefore, gave me an opportunity of studying the characteristics of till or boulder clay which had been deposited or formed on a rising slope partly below sea-level. Other conditions which presented themselves later were unknown to me at that time.

We have seen that there are a few exposures of limestone near the shore of Hudson bay; then for a long distance inland that no hard rock is to be seen, and that the next rock which we met with, both on Hayes river and on the Severn, was bare, smooth granite. Evidences of glaciation were everywhere to be seen on the rocks exposed, though they were not always readable; but in the extensive intervening areas, where no rocks are exposed, the evidences of the direction of glaciation were not so apparent or clear.

On the rocks themselves, the most conspicuous evidences of glaciation to be found, of course, were the grooves and striæ left by the glacier. These grooves, etc., were made by a glacier pushing sand, boulders, etc., over the rock, and this layer of sand and boulders which was pushed over the rock is what is here called till.

Now, in some places there are two or three distinct layers of till, one of these lying immediately on the rock, while another one is higher and may be separated from the lower one by a bed of clay, sand or even lignite. It is clear, in such cases, that the lower bed has not been moved since it was first packed down on the rock by the glacier, and it is also clear that the second glacier, which packed the second till on top of the first would not form grooves and striæ on the rock which lay under the undisturbed till. Therefore the grooves and striations represent the direction of movement of the lower till where two or more tills are present.

STRIATIONS.

First, as to the direction in which the till was moved, as shown by the striations and grooves on the rocks wherever the rocks have been uncovered, and where the markings can be detected.

Beginning at the mouth of Severn river where it flows into Hudson bay and ascending it for twenty-eight miles, Limestone rapids are reached. Silurian limestones are exposed for a mile or more in the bottom of the valley at this point, for here the river has cut through the till to the underlying rock. In the middle of the valley, where the limestone has been exposed to the water and air for the longest time, the glacial markings have been removed from its surface; but at the sides of the valley, where the till has but recently been washed away, the general surface of the rock is scored S. 55° W., showing the direction of movement of the last or Labradorean glaciation, while, in a few depressions, scorings of an earlier glaciation, running N. 5° E., are quite plain. The till overlying the rock at this place was without any horizontal dividing line, and probably all belonged to the Labradorean period.

For seven miles farther up the river glacial grooves and striæ were very abundant close to the foot of the overlying bank of till on the east side of the river—the side on which I walked—and all were trending from N. to N. 10° W. The direction of movement was often clearly shown by the rounded sides of the knolls facing towards the south and the broken sides towards the north, the crescentic fractures opening northward, etc. As the adjoining cliffs of till were wooded, and much slidden, it was impossible for me to examine them very closely in the time at my disposal, but it is probable that a lower till, formed by the glacier from the south, which is here called the Patrician glacier, rests directly on the rock, and that this till supported the later Labradorean glacier in this place and prevented it from reaching and scoring the underlying rock as it would have done if the bottom till had been absent.

Thence for 20 miles scorings were not observed, after which the rock was found to show glacial striae of the Labradorean glacier running S. 60° W.

The general surface of the limestone at the uppermost limestone exposure on Fawn river is also similarly scored, but just at the south end of the limestone hill, where the rock drops away and where it has been protected from the Labradorean glacier by the slightly higher rock to the north, it shows the Patrician glaciation running N. 10° E.

South of this limestone no rock is exposed on Fawn river for 75 miles measured in a straight line, and the banks are cliffs of till, in which there is usually a distinct horizontal line dividing it into upper and lower portions. Just beneath this line a boulder pavement is sometimes found with the upper sides of the boulders flattened and scored, showing that the pressure of the upper on the lower till has been severe, and that the planing action has been considerable. The directions of the scorings on several of these boulders were N. 10°–20° W., or the opposite. This would indicate that the upper of these tills was that of the Patrician glacier, and that the lower till was of a still older glacier, the direction of movement of which has not yet been determined. More observations, however, would be necessary to decide this question.

At the lowest exposure of granite on Fawn river the grooves and striæ of the first glaciation run N. 30° W. while those of the last glaciation run S. 40° W. South of this none but the scorings of the last (Labradorean) glaciation were seen until we reached the twelfth portage, after which the first glaciation was recognizable at several of the rapids and portages, running N. 15°–30° W., while the last was running S. 40° W.

On the shores and islands in Trout lake the conditions are very characteristic and their meaning is unmistakable. The islands are rocky knolls rising above the surface of the water. Instead of showing strong stoss and lee sides, as is common throughout most of northern Canada, they slope gently on almost all sides, occasionally showing a little broken cliff towards the west.

On closer examination they are seen to have been strongly scored, first by a glacier which came from the southeast and moved N. 25°-40° W. and which was clearly the Patrician glacier, and afterwards by the Labradorean glacier moving S. 35°-40° W. The same conditions are evident on the shores, but the conditions for showing the two glaciations are not always so ideal as on the islands.

In the country south of Trout lake the conditions as shown by the scorings are not always as clear and distinct as in the country north of it. We passed to the west of the centre of the Patrician glacier, and its moving ice doubtless swung farther to the west, and later to the south of west nearer to the direction of the later Labradorean glacier. At the same time the blanket of till left on the country is much thinner than farther north and is often intermittent, so that the rock surfaces have not been protected by it and are consequently more weathered and do not preserve the scorings like those farther north. In no cases were the two glaciations distinctly recognized on the same rock in the country south of Trout lake.

From Trout lake south to Windigo lake, a distance of 90 miles, glacial scorings, varying from S. 20° W. to N. 65° W. were observed in thirteen different localities. Most of these trend S. 55° W. and undoubtedly are markings of the Labradorean glacier, but some, and especially two on Makoop lake that trend W. and N. 65° W. were probably made by the Patrician glacier.

On Windigo lake the scorings vary from S. 5° W. to S. 15° E. and would appear to have been made by the Labradorean glacier when it terminated at the great moraine which crosses the country south of that lake. Whether or not the Labradorean glacier ever extended south of this great moraine, which I have later called the Agutua moraine, is somewhat uncertain.

On Cat river above Lake St. Joseph the direction of striation is about S. 55° 65° W., and I have no means of telling whether these striæ and grooves were caused by the Patrician or the Labradorean glacier; but it is reasonably certain that the Patrician glacier, lying on the high lands south of Hudson bay, must have flowed southward and southwestward, and it does not yet seem equally certain that the Labradorean glacier must have extended southward over the same slope.

For a long distance west of Severn river the country is but slightly explored and no critical examination of the glacial conditions has been carried out.

At the lower Limestone rapids on Shamattawa river the surface of the limestone is rough and weathered right up to the edge of the till, and it is not improbable that it was never subjected to severe scoring.

At and near the lowest exposure of granite on Hayes river several glacial scorings are apparent. The oldest ones vary from S. 65°–S. 85° W. and were formed either by the Patrician or the Labradorean glacier, while the later ones trend S. 20° E. and have doubtless been formed by a readvance of the Keewatin glacier. Farther upstream, on Oxford lake and vicinity, the direction of Labradorean glaciation is S. 59° W.

TILL.

The till varies considerably in character along Severn river from its source to its mouth, and throughout the country westward to the mouth of Nelson river. All this country slopes gradually northward towards Hudson bay from an elevation of 1,500 feet down to sea-level, giving it an average decline of about five feet to the mile. The Patrician glacier descended this slope from the south northward, while the later Labradorean glacier, on the contrary, ascended it from the northeast southwestward, forming a great moraine near the summit.

On the upper part of this slope, above the level of Trout lake, the till is irregular and uneven and is often more or less morainic in character. The rounded tops of the rocky knolls often rise above it and may be bare of clay, boulders or detritus of any kind, the trees or other vegetation in such places growing directly out of cracks in the rock. Nevertheless, the depressions in the rocky surface are usually filled or partly filled with a pebbly or stony clay. Where there are no rocky prominences the whole surface may be covered with this clay, so that no rock may be observable in the country for long continuous distances. Unlike the country farther south, the lakes do not occupy rock-basins but rather irregular depressions in the clayey surface, and the outlets are usually protected and sustained by barriers of large rounded boulders.

Similar conditions prevail for a short distance north of Trout lake, and then they change very materially, so that in the vicinity of the last exposure of granite on Fawn river, the tributary of Severn river which I explored, the country becomes covered with a great sheet of clayey till containing comparatively few boulders. Thence the till extends continuously down the river to the shore of Hudson bay, though for the last few miles it is covered by later marine sediments.

A similar sheet, or a continuation of the same sheet of till, extends down Hayes river from the vicinity of Swampy lake, at an elevation of 500 feet, to the shore of Hudson bay at the mouths of Nelson and Machichi rivers, though the lower part of Hayes river itself appears to flow in an old valley where the till was either particularly thin, or where it was not deposited. Similar till occurs on the lower portion of Shamattawa river and on Machichi river, which is a small stream just east of Hayes river; but thence eastward across the country to Severn river very little is known about the character of the surface deposits.

The till in all these localities is very similar in character. As a rule it is a highly calcareous clay composed of subangular grains of quartz and limestone mixed with a large amount of partly decomposed argillaceous material, and occasionally with small fragments of marine shells. It contains many small, slightly angular pebbles and a relatively small number of boulders, many of which are more or less distinctly scored with glacial markings. The boulders are chiefly of granite, but some are of a brownish gray, calcareous quartzite, on which rounded spots weather out to a whitish colour, giving them a characteristic ocellar appearance; others are of red conglomerate, white and red sandstone, green diabase, banded ironstone, and fossiliferous Silurian limestone. The till is unstratified and its lower and harder portions break out into angular masses of roughly cubical shape. In some places it is seen to be divided into an upper and lower portion by a distinct horizontal line of division, though both portions are very similar in character, except that the upper is usually a little darker and more oxidized.

On the Severn and Fawn rivers the upper till commonly rests directly on the lower, with a pavement of striated boulders at the top of the latter.

On the Hayes and Shamattawa rivers there is usually a layer of stratified sand between the two beds of till, with moss and fragments of coniferous wood in the sand and in the bottom of the upper till, indicating that the pressure and scoring was lighter here than on Severn river in consequence of being nearer to the western margin of the glacier.

With regard to the extension of the continuous sheet of till into the country east of Severn river, there is no doubt about its occurrence on Winisk river, 95 miles to the east, for the description given by Mr. McInnes, of the glacial deposits along its banks, show that they agree closely with those in the country through which I travelled.[1]

In my opinion there is no question that this till is principally a marine deposit which has been kneaded by an overriding glacier along with pebbles and boulders into a homogeneous mass; and further that the general extension of this great sheet of till over the country up to a level of about 500 feet above the sea has some close relationship to the former extent of the pre-Glacial or inter-Glacial marine sediments from which it has been largely derived. Judging from the character of the included boulders and pebbles of limestone, etc., it is also evident that the till was kneaded into its present condition by a glacier moving southward.

MORAINES.

No moraines which could be definitely ascribed to the Patrician glacier were observed, though many of those south of the source of the Severn river may have been formed by and in front of it.

On the slope northward down Severn river there are many moraines, the two most conspicuous of which I have called the Agutua and the Kawagami moraines. Both of these exhibit the typical land-laid character, and both of them were formed in front of the Labradorean glacier.

Another important moraine, which crosses the country from west to east, was evidently laid in the water. As this crosses Fawn river near the mouth of Poplar or Metoos river I propose to call it the Metoos moraine. It is probably continuous with the hills near the mouth of Shamattawa river.

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[1] William McInnes, "*Report on a part of the North-West Territories drained by the Winisk and Attawapiskat Rivers*," Geol. Surv., Dept. of Mines, Canada, 1909, pp. 19-22.

ESKERS.

Near the headwaters of the Severn river, and at "The Hill" or "Chacutinow" on the east bank of Hayes river, are ridges of sand and gravel several hundred feet in height which are associated with moraines and have been formed close to the front of the Labradorean glacier. In the latter locality these sand hills were probably formed when the Labradorean glacier was confluent or nearly confluent with the face of the Keewatin glacier during its latest advance. During the formation of these enormous eskers the water had free drainage away from the Labradorean glacier, either over the lower country farther south or, as at "The Hill" on Hayes river, possibly down into Hudson bay between the faces of the Keewatin and Labradorean glaciers.

South of the source of Severn river the land falls away gently to the south. On this southern slope are many narrow sand ridges or eskers running parallel to the direction of striation on the underlying rock, but none of these ridges have the magnitude and strength of those on the watershed between the Severn and Albany rivers, or of "The Hill" on Hayes river.

POST-GLACIAL DEPOSITS.

The scope of this paper does not include a discussion of the character and extent of the post-Glacial deposits of the region visited during the past summer, but a few words about them may not be out of place.

While the Labradorean glacier was retiring towards the northeast at the close of the Glacial period, extra-glacial lakes were formed in the valley of Hayes river in the vicinity of the present Oxford and Knee lakes. But on the upper waters of the Severn river, where the land was higher, the drainage from the glacier was doubtless parallel to and along the face of the ice sheet, and such extra-glacial lakes with their lacustrine deposits of sand and clay are not represented.

When the glacier had retired northward down the slope to a line where its front was below the level of the sea at that period, sea water flowed around in front of it. As the face of the ice continued to retire, the area of open sea increased, and a sheet of clay and sand was deposited in the bottom of this sea on the top of the underlying sheet of till. In most places these marine sediments are rather thin, but on the lower part of Hayes river, where they fill an old valley which had probably been formed along the western side of the Labradorean ice-sheet, they are very much thicker than usual.

As the glacier retired northward the land rose, and sea beaches of sand and gravel were formed one below the other as the shore line of Hudson Bay receded northward to its present position.

SUMMARY.

The conditions, as far as they were determined last summer in the District of Patricia and in the adjoining parts of Manitoba, were somewhat as follows:

A great glacier, here designated the Patrician glacier on account of having its centre or gathering ground in the District of Patricia, had its centre somewhere on the higher lands southeast of Trout lake, and discharged its ice northward and northwestward into Hudson bay, and doubtless also westward and southward, in the latter direction probably into the basin of Lake Superior.

Subsequently this Patrician glacier dwindled away and finally disappeared from the land sloping northward into the bay, and quite possibly from the whole country farther south.

During this retirement and disappearance of the Patrician glacier a great thickness of marine sediments was being laid down in the bottom of Hudson bay, the land probably standing at a lower level than it does now, and the water area being consequently larger than the modern Bay. The marine sediments would therefore probably be deposited on some of the lower portions of what are now land.

Then a great glacier, here spoken of as the Labradorean glacier, though its exact gathering ground is not yet certain, advanced from the northeast, ploughed its way through the shallow basin of Hudson bay, and advanced at least as far southward as the headwaters of Severn river, carrying the marine sediments from the bottom of the Bay along with it, and at the same time kneading and pressing them into the compact sheet of till which covers all the lower country to a distance of about 125 miles inland from the present shore of the Bay.

The formation of this great sheet of till was consequently dependent upon the existence of an abundant supply of soft unconsolidated material ready to be moved along and kneaded up by the Labradorean glacier, rather than upon the material which was scraped and torn by the glacier itself from the underlying hard rocks over which it travelled.

It seems probable that much of this material was not moved by the glacier for the whole of the above distance of 125 miles, and consequently that the marine sediments laid down in Hudson bay in Patrician or pre-Labradorean time extended farther inland than the present shore. Possibly the Patrician seashore was not far from the present southern border of this continuous sheet of till.

On the high land near the source of Severn river the Labradorean glacier formed a great moraine, in connection with which were a number of huge sand ridges or eskers.

After it had reached its greatest southern extension it retired and left a number of stony morainic ridges across the higher part of the country, and dropped a great water-laid moraine in the salt water of Hudson bay before it finally retired from the country.

It is not certain how far the Patrician glacier advanced towards the west, but the Labradorean glacier would appear to have had its western front or side about at Hayes river, where it was met by a readvance of the Keewatin glacier from the northwest.

When the Labradorean glacier began to retire northward the land beneath it was lower than it is at present. When its front reached the sea-level of that period the salt water of Hudson bay flowed round it. Then marine sediments were deposited on top of the previously formed till, and as the glacier continued to retreat northward the land continued to rise until, with the disappearance of the glacier, it attained its present elevation and condition of stability.

DISCUSSION.

F. LEVERETT (Ann Arbor, U.S.A.) mentioned what seems corroborative evidence of a Patrician centre in the peculiar distribution of copper in the glacial drift in the east-central part of the United States. It had been carried into central Ohio and over all of Michigan and Indiana apparently by an early southeastward ice movement that passed across the copper-bearing rocks of the Lake Superior region. The later ice invasions, both Illinoian and Wisconsin, crossed these states by a southwestward movement from Labrador and could not have passed the copper-bearing formations on the way. This would seem to indicate a Kansan or pre-Kansan movement from the region north of Lake Superior, that is, from the Patrician centre.

The peculiar ice movements in the Wisconsin stage of glaciation in Minnesota seem also to call for a movement from the Patrician centre as well as from the Keewatin centres. Ice from the Labrador centre filled the Lake Superior basin in the Wisconsin stage. Ice from the district north of Lake Superior moved in a S.S.W. course into Minnesota, producing the sheet of red drift west of the Superior lobe as far as Lake of the Woods on the west, and as far as St. Cloud and Belle Plaine, Minnesota, on the southwest. When this ice had melted away, the Keewatin ice came into the northern part of Minnesota past Lake of the Woods and Rainy lake, and even crossed the Mesabi iron range. The Patrician centre seems, therefore, to have become greatly reduced on the southern side as well as on the northern side early in the Wisconsin stage.

DISCUSSION SUR LA QUESTION: DANS QUELLE MESURE L'ÉPOQUE GLACIAIRE A-T-ELLE ÉTÉ INTERROMPUE PAR DES PÉRIODES INTERGLACIAIRES?

H. B. KÜMMEL (Trenton, U.S.A.): In New Jersey the southern margin of the extra-morainic drift lies in a region from 100 to 250 feet and more above sea-level. Hills having an elevation of 200 feet and more above sea-level are generally drift-capped, but the drift does not in general extend much below their summits. The present elevation of the larger streams of the region is less than 100 feet and the valleys are maturely developed. In fact, there is a very much greater area below 200 feet elevation than above it. The evidence is very strong that the drift was deposited upon a former surface with an elevation of from 200 to 275 feet, although an occasional valley may have been slightly lower. Since the deposition of the drift the streams have excavated valleys that are over 100 feet in depth and possess very gentle slopes. As the elevation of the region is not great and its distance from the sea is 30 or 40 miles, the time necessary for the development of such mature valleys was long. For this, as well as for other reasons, the workers in New Jersey are convinced that the extra-morainic drift in New Jersey is of great age as compared with that of the moraines. Since the extra-morainic drift of New Jersey is continuous with that of eastern Pennsylvania, we are forced to dissent from the conclusion that the glacial fringe or attenuated glacial border is, as a whole, of recent date. It must be recognized, however, that during the Wisconsin epoch the ice may have locally advanced short distances beyond the moraines, so that in places young drift may have been incorporated into the older drift of the attenuated border. This may account for some of the indications of youth cited by Professor Wright.

F. FRECH (Breslau) bemerkt dass die Frage der Einheitlichkeit oder mannigfachen Teilung der Eiszeiten in erster Linie von der Selbständigkeit einer interglazialen Säugetierfauna abhängt. Da eine solche bekanntlich fehlt während die ganze vorangehende Tertiärfauna unter dem Einfluss der klimatische Wechsel steht, ist die Frage vielleicht nur unrichtig formuliert. Dass ein mannigfacher Wechsel von Vereisungen und eisfreien Zwischenlagen Nordamerika mit Europa kennzeichnet unterliegt keinem Zweifel. Aber die verschiedenen Vereisungscentren haben sich selbständig entwickelt: Norddeutschland weist drei, die Alpen vier, das zwischen beide liegende Riesengebirge nur zwei Vereisungen auf. Also handelt es sich um ein sehr verwickeltes Phänomen, bei dem, abgesehen von dem Wechsel der Wärme, die lokale Verschiedenheiten der Niederschläge und in der Nähe von Hochgebirgen die durch seismisch (wie in Alaska) bedingte Gletschervorstoss in Betracht kommt.

A. P. COLEMAN (Toronto) was of the opinion that there was one universal inter-Glacial period as opposed to Professor Frech's view that there were partial advances and retreats in different parts of the world. High mountains in all parts of the world show at least two glacial deposits with an inter-Glacial interval which was almost certainly world-wide. The evidence from mammals cited by Professor Frech did not seem conclusive as against this.

G. F. KAY (Iowa City, U.S.A.): Dr. Coleman referred in his paper to the inter-Glacial deposits in the vicinity of Toronto, and expressed the opinion, based on the faunal and floral evidence of these beds, that they are probably closely related in age to the Aftonian of Iowa. In this connection I am sure that it will be of interest, particularly to our European friends, to show by means of lantern slides some of the interesting fossils, especially the extinct mammals, that have been taken from the Aftonian gravels and sands of Iowa. These remains are in many cases not abraded or worn in the slightest degree. Moreover, the relations of the bones one to another in the beds indicates in many cases that the animals were floated into their present positions while the parts of the skeleton were still intact. These facts, and others which could be presented, can be explained only upon the basis that these remains are not pre-Aftonian but are of the same age as the Aftonian gravels themselves.

(Slides were shown of the remains of fossil horses, mammoth, mastodon, camel, beaver, deer, sloth and bear from the Aftonian of Iowa.)

F. LEVERETT (Ann Arbor, U.S.A.), spoke of his impressions of the British drifts on the east coast of England, visited with Mr. LAMPLUGH. The drifts are from different ice-fields, the lower from Scandinavia, the upper from Scotland, and are both fresh as compared with the relations found in Minnesota, where gray drift from Manitoba overlies red drift from a district further east. Mr. LAMPLUGH does not mention the very great age of the chalky boulder clay near London, which is now preserved only in small remnants on divides, and which represents a drift comparable with one of our older drifts. The contrast between this greatly eroded drift and the very slightly eroded drift on the east coast north of Hull would constitute an excellent example of the length of the time separating the two drifts.

Mr. LEVERETT referred to his paper, *Comparison of North American and European Glacial Deposits* published in 1910 in the Zeitschrift für Gletscherkunde, and said that he now understands that the interpretation of North German drifts given in this paper is thought by leading German geologists to be incorrect, in that the most extensive drift is to be correlated with the Riss drift rather than with the Mindel.

M. B. BAKER (Kingston, Canada): I would like to add some striking evidence of a long inter-Glacial period which I observed in the field two years ago. While working about the southwestern coast of James bay, I observed inter-Glacial beds of lignite coal, underlain by drift, which subsequently had been eroded and again overlain by glacial drift. The bed-rock of this area is Lorraine limestone. This limestone is glaciated and overlain by from 30 to 50 feet of boulder clay. Immediately above this is a series of bedded clays and sands carrying seams of lignite as much as six feet thick. This lignite series was ploughed and eroded by glaciation so that above it lies from 30 to 70 feet of glacial drift, many of the boulders in which are lignite. This fixes the age as inter-Glacial.

From the lignite beds I dug several trees, the largest being 17 inches in diameter. Subsequent study showed it to be *Abies balsamea* and two others have been identified as *Populus balsamifera* and *Thuja occidentalis*. In my work in northern Ontario I have not been able to find a balsam tree 17 inches in diameter. There has not been sufficient amelioration of climate since the retreat of the ice-sheet to permit the growth of such a tree. I maintain, therefore, that we must have had an inter-Glacial period in Quaternary time much longer in duration than is the time intervening between the last retreat of the great Labradorean sheet and the present, for not only was a tree grown larger than any of the present examples of the same family, but it was buried, converted into lignite and again bared by ice erosion, so that rounded boulders of the lignite are found in the overlying drift.

G. F. WRIGHT (Oberlin, U.S.A.): Professor COLEMAN's estimates of the age of the present Lake Ontario correspond closely with my own estimates based on the amount of stream erosion in Ohio south of Lake Erie. But his higher estimates for Lake Iroquois are greatly in excess of what is possible, if my estimates on the shores of old Lake Warren in Ohio are approximately correct. Lake Iroquois was much younger than Lake Warren, yet that lake cannot have been more than 12,000 years old. There must be some error in Professor COLEMAN's estimates for the earlier period. The rapidity of possible changes in glacial conditions is strikingly illustrated in those which have taken place in the Muir glacier, Alaska, since my survey in 1886. Since then the front, one mile and a half wide and rising 300 feet above the water of the inlet, has retreated seven and one-half miles, and the surface has lowered by melting 700 feet.

W. WOLFF (Berlin) bemerkte etwa Folgendes: Nach dem gegenwärtigen Stand unserer Kenntnisse erscheint es unmöglich, in Deutschland eine, nämlich die "ältere" Interglazialzeit zu verneinen. Interglazial im strengen Sinn können nur solche Ablagerungen genannt werden, die ein vollkommen gemässigtes Klima und einen sehr weiten, wenn nicht vollständigen Rückzug der Inlandeisdecke zur Voraussetzung haben. Dies trifft für das ältere Interglazial Norddeutschlands ein, zu dem marine Ablagerungen im Westen und Osten des Landes gehören, das somit völlig eisfrei gewesen sein muss. Die stratigrafischen Verhältnisse mancher Ablagerungen des zweiten, jüngeren Interglazials erscheinen mir dagegen weniger klar, und wenn nicht Botaniker und Zoologen so entschieden für die Annahme einer wirklichen Wärmeperiode einträten, würde ich die Lagerungsverhältnisse nicht in diesem Sinne deuten. Mir erscheint die Frage durchaus diskutabel, ob nicht ein grosser Teil dieses jüngeren Interglazials in Wahrheit interstadial ist. Alles hängt, meines Erachtens, von der Lösung der Frage ab, wo zu jener Zeit der Pol gelegen hat. Lag er an derselben Stelle wie heute, so empfing unser Land im Sommer ein gut Teil Wärme und Licht und blieb im Winter ausserhalb des Schattens der Polarnacht. Dann aber war selbst während einer Vergletscherung gemässigte Fauna und Flora in der Aussenzone möglich.

WARREN UPHAM (St. Paul, U.S.A.), regarded the sections of inter-Glacial beds in the Don valley at Toronto, and at Scarboro' cliffs not far to the east, which have been grouped together by COLEMAN and CHAMBERLIN under the name of the Toronto formation, as the most important evidence and record of inter-Glacial conditions yet known in America, being probably not surpassed anywhere in the world.

F. B. TAYLOR (Fort Wayne, U.S.A.), stated that there was evidence at Niagara of an interval of post-Glacial erosion which could not have been less than 15,000 years.

Sujet No. 7: Les caractéristiques physiques des mers paléozoïques et les particularités de leur faune considérées au point de vue de la portée du retour des mers dans l'établissement des systèmes géologiques.

THE SHELF-SEAS OF THE PALEOZOIC AND THEIR RELATIONS TO DIASTROPHISM AND TIME DIVISIONS.

BY

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It will be agreed at once that the general configurations of the oceanic beds are due to deformative processes. If we may also agree that the same is true of the beds of some of the seas, the way will be cleared for making special note of sea-beds that do not owe their final form to diastrophism but to gradational processes. If all of the one class, large and small, be grouped as diastrophic basins, all of the other class may be styled gradational basins, however incomplete the basin form. There are of course composite forms that must be neglected. The most familiar examples of the gradational type are the continental shelves. These are regarded as only initial forms of the type, falling much short of ideal representatives of mature sea-shelves. The waters that rest upon these sea-shelves may be known conveniently as shelf-seas.

The ideal shelf-sea is not independent in origin; it is conditioned by the diastrophic sea from which it grows; diastrophism shapes the original basin; gradation superposes certain characters and extensions upon it. These new features are of high importance in biological and stratigraphical development.

Not only are shelf-seas conditioned at the outset by diastrophism but their histories are dependent on its continued or its interrupted action. If diastrophism is continuous the gradational process constantly suffers disturbance and is ineffective; if diastrophism is periodic gradation goes forward as long as quiescence continues, attaining greater and greater degrees of maturity and ceasing only when its work is cut off by renewed diastrophism. If diastrophism is periodic, effective gradational results are interperiodic; diastrophism and gradation are alternately dominant. From this general conception, let us turn to specific characters.

The distinctive features of shelf-seas are these:

I. *There is a close approach to parallelism between the surfaces and the bottoms of these seas.* There is but a gentle slope between their landward sides and their seaward sides or their deepest axes. In their earlier stages the typical slopes may be 1 in 1,000, or in 800, or perhaps less; in their maturity the slopes seem often to have fallen to 1 in 2,000 or 3,000, or lower. This close approach to parallelism between surface and bottom is a feature of moment in its bearings on the nature of the deposits and the character of the life.

II. *The parallelism between sea-surface and sea-bottom is close in the further sense that the planes lie near one another.* For reasons inherent in the gradational processes, the sea-shelf is limited in depth. Beyond a certain depth of water effective transportation of sediment fails, and the further growth of the shelf is checked until the depth in front is filled. For the limital depth let us assume 600 feet, 200 metres, 100 fathoms, the recognized mean depth of the outer edge of the present continental shelf. Let considerable variations from this be recognized as consistent with the type, but this figure may serve as representative. Exactness in this particular is not material to the purposes of this discussion, for the distinctions to be drawn are so broad that great latitude is permissible without invalidating the arguments built upon them. The natural criterion of the type is that depth at which the agitation of waves, tides and currents ceases to keep in effective suspension or in rolling condition the terrigenous silts of those classes that embrace the larger parts of the earthy matter derived from the land. The extremely fine material that may float long with little motion is negligible as it does not build up the bottom apace with the more bulky constituents. The shelf is thus a product whose physical features are determined by its own conditions; it is a self-regulated formation, the guiding element in whose genesis is the sea-surface and the agencies that play upon it.

III. *The sea-shelf is definitely correlated with the penetration of solar rays.* This is a relation of biologic moment. As the mode of formation keeps the face of the shelf within a certain distance from the sea-surface, the waters upon it have a rather definite range of illumination. Competent opinion places the larger part of the effective photo-synthetic action within a hundred metres of the surface, while photographic effects vanish at three or four hundred metres. Organisms that depend on insolation, or that live upon those that do, may be assumed to be rarely fossilized at greater depths than these when there is no ground to suspect post-mortem transportation. The shelf-sea deposits, therefore, embrace the photosynthetic types and their dependencies, sessile and mobile alike. Deeper deposits may embrace the pelagic types, but rarely the sessile and quasi-sessile forms. The shelf zone is therefore, from the very nature of the case, a biologic horizon of the first importance. Its faunas, in consequence, belong to a distinctive type. The life entrapped in the bed of the shelf-sea is demarked from that caught in the abysmal bed of the ocean. There is, however, a narrow belt about the borders of diastrophic seas that enjoys photo-vital conditions much the same as the gradational shelves, though the slopes are normally steeper and the life conditions somewhat more special and precarious in general. A comparison of the relative values of the gradational shelves and the diastrophic belts within the same depth limits is a critical part of this study and will be taken up presently. It will appear that the shelf-seas are photobathic zones of special effectiveness, and are, and no doubt always have been, the habitat of a most important type of marine faunas and floras, the class most akin to the life of the land,—preëminently the class on which the divisions of geologic history have been based, and may best be based still more specifically.

IV. It is scarcely more than a reiteration of the last statement in a more special form to say that the faunas of the shelf-seas of the Paleozoic were given distinctive aspects by the conditions of insolation, of aeration, of low pressure and of unagitated bottom, all of which were determined by the mode of origin of these seas. These sea conditions became, therefore, critical factors in the history of Paleozoic life. The extent and maturity of these seas was thus a decisive factor in Paleozoic history.[1]

V. So, too, it is scarcely more than reiterating the statement that preceded the last, to say that the typical sediments of the shelf-seas of Paleozoic times were of the types that depend on agitated waters. The sediments were assorted and spread out with notable uniformity, continuity and exceptional horizontality over wide tracts because of the conditions of formation.

VI. *The shelf-seas were spread upon the continental platforms.* Diastrophic sea-basins may be *set in* between continents (Mediterranean, Caribbean, etc.) or be *sunk within* the continental platforms, but the gradational seas lay upon terraces either built out from the upper edge of the continental platforms, or cut back on the upper edge of the platforms, or else were flooded forth upon the lower parts of the platforms by the partial filling of the ocean basins with sediment. They were technically epicontinental, while the diastrophic seas were usually intercontinental or intracontinental. Of course, shallow diastrophic basins may be so formed as to be in a sense epicontinental but not in the constructive sense here applied to the sea-shelves, and of course there were composite types not belonging wholly to either class.

Diastrophic limitations.—Let us now consider the degree of competency and of incompetency of diastrophism to produce shallow seas whose deposits and faunas may be comparable in any serious sense with those of the shelf-seas.

If the earth-body were a perfect spheroid of revolution completely adapted to its own conditions, and if the volume of the hydrosphere were essentially what it is to-day, there would be a perfect parallelism between the sea-surface and the sea-bottom of the universal ocean that would be the inevitable consequence of these conditions, but there would be no sediments of the common kinds, nor any life of the more familiar fossil types, except the pelagic and the abysmal. The picture of such a state of the earth, and of such an evolution as might arise from it if indefinitely prolonged, is as far as possible from that which geological history really presents at any known age. The actual earth has a deformed surface of such proportions that about one-third is continental protuberance and two-thirds abysmal depression, with connecting slopes between. At present about one-sixth of the continental protuberance is covered by epicontinental seas, and this sixth adjusts the one-third-two-thirds ratio to the more familiar one-fourth-three-fourths

[1] This of course holds of other eras also, but they are not included in the theme to which this paper is limited.

ratio of land to water so successfully inculcated by the geographies. It is the one-third-two-thirds ratio of body-protuberance to body-depression that concerns us in deformative studies. In these studies the modification imposed by the sea-shelf work is an incident.

These proportions have been taken of course from the present status. If it is suggested that a quite different ratio may have prevailed in early geologic times and that the ratio in the Paleozoic era may have been so far different as to leave little value in this present ratio, it may be replied that no special weight is rested on this ratio as such. It is merely convenient for use in forming a concrete conception of the work of deformation taken in its largest sense. It is my belief, however, that the ratio of protuberance to depression as defined by the sea-level has not radically changed from the beginning of the Paleozoic to the present time, but geologists entertain varying opinions on this point.

It is becoming more and more clear as study proceeds that the great deformations that determine the ocean depressions and the continental protuberances are not mere superficial incidents of the earth's development. One of the latest geodetic inquiries into the distribution of gravity finds that the outer part of the earth in the United States only reaches a state of isostatic equilibrium at a depth of seventy odd miles, even when an extreme hypothesis of the distribution of differences of specific gravity is made the basis of interpretation.[1] If a natural dying away of the differences of specific gravity from the surface downward is made the basis of interpretation, the depth is increased and may be more than doubled.[2] The geodetic data of India, a land of great deformations, seem to demand much greater depths than the data of America.[3] Considerations that lie in the mechanics of the case strongly support the view that the portion of the earth that is involved in the great deformations is both thick and stiff.

Now in the deforming of a spheroid whose outer parts are so stiff as to take on and to maintain broad inequalities like the continents and oceanic basins, certain mechanical results are inherent and inevitably express themselves in the configurations; for example, the portions that are most nearly horizontal will, in the nature of the case, be those at the bottoms of the sags and the tops of the swells. These portions are nearly tangent to horizontal planes. The dips of the surface will naturally become greater at points intermediate between the swells and sags. If, therefore, the sea-surface lies at such a position that one-third, or one-fourth, or some considerable fraction of the upper portion of the warped surface is above it, and a still larger fraction, two-thirds, or three-fourths, or some such fraction is below it, the zone of shallow water will usually cut the warps at points where they have relatively high dips. The area between the water-surface and the shelf-

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[1] JOHN F. HAYFORD. *The Figure of the Earth and Isostasy from Measurements in the United States*; Coast and Geodetic Survey, Washington, D.C., 1909.

[2] Loc. cit., p. 159.

[3] G. S. BALLARD. *On the Origin of the Himalaya Mountains, a consideration of the Geodetic Evidence*; Prof. Paper No. 12, Survey of India, 1912.

limit in depth will therefore be proportionately small. For a rough illustration, if the average crests of the continental swells be t. , at the modest figure of 6,000 feet above sea-level and the average bottoms of the oceanic sags at 18,000 feet below sea-level, the vertical depth of 600 feet spans only one-fortieth of the total range. The value of this fraction has yet to be reduced for the excess of slope of this portion over the mean slope to give the horizontal breadth of th belt really embraced within the shelf-depth.

At the present time th extreme range of deformative heights and depths is more than twice that selected as the basis of this illustration.

An inspection of present conditions seems to show that the sea-surface so cuts the normal unmodified diastrophic surfaces that an area not more than half that of the present continental shelf would lie between the contours of zero and of 600 feet depth, or perhaps 2.5% of the earth's surface. This differs radically from the broad areas of shallow water that obtained at the climax of great sea transgressions in Paleozoic times, when from 40% to 50% of the surface of the North American continent was covered, i.e. from 16 to 20 times as much. Comparable portions of other continents were covered in the same way and at the same time. That these transgressive seas were shallow is implied by the sediments and by the faunas alike.

Various other modes of inspection lead to results of like order. The discrepancy is so great that the elements of the estimate may be liberally changed to cover all legitimate sources of doubt without affecting the general tenor of the results.

If the borders of the continents be thought to be affected by faulting in some special degree, the incompetency of diastrophism in this respect will be emphasized rather than mitigated, for the usual effect of faulting is an increase of the steepness and abruptness of the descent from the land to the deep sea.

These facts seem, therefore, to force a consideration of the proposition that the ordinary diastrophism of the earth is not suited to cause the shallow-water seas which the geologic record presents for interpretation.

If, to escape the force of this proposition, one indulges the inherited habit of assuming that a flat area from the sea-bottom "might have been" lifted to just the right height or let down from the land area to just the right level for this specific shallow submergence, it is well to note that the right height is only a small fraction of the full range of height involved in deformation and that the chances of the close adjustment required are correspondingly small, and should be correspondingly infrequent, as well as irregular in distribution, whereas the actual case presented by the Paleozoic seas is a systematic repetition of this state from period to period, combined with similarity of action in different continents.

If one indulges in the familiar old idea of a slow subsidence to sea-le and below, he takes refuge in the most plausible of all diastrophic devices for meeting the actual case, if indeed such slow subsidence really is a diastrophic movement at all, in the ordinary sense. In pure theory, a downward diastrophic movement has little advantage over an upward one in meeting the demands of this case. It is, however, supplemented by gradation. It is commonly assumed in this case that the deposits build up the sinking area as fast as it descends and thus preserve an adjustment to the sea-surface. Now if the rate of deposition and the rate of subsidence were inherently correlated with one another so as to be coöperative in the same phase, such an adjustment would be natural and be often repeated and so meet the requirements of the case to this extent. If, for example, the weighting due to deposition were sufficient to cause proportionate subsidence, the adjustment would be easily and naturally maintained when once made. This would happen if the earth-surface were in free isostatic adjustment to this degree of nicety and the stiffness of the crust offered no effective resistance to continuous warping. On the adjacent land, however, whence the material for the deposit is being taken, the unloading should cause a proportionate rise and the sea transgression be defeated.

If, however, general elevations and subsidences are dependent on differential stresses in the body of a very stiff, elastic earth capable of accumulating strains of high value, the case is very different, for the crust movements are not immediately responsive to loading and unloading which can only induce a slight strain or elastic yielding in the stiff, elastic body. No nice adjustment to deposit can be assumed in this case. In my judgment the phenomena of geology and related sciences support this view and are distinctly opposed to an adjustment by loading and unloading of this degree of nicety.

A close adjustment in response to loading and unloading seems on first thought to be supported by views of isostasy that have recently been put forth on the basis of elaborate studies of geodetic data, but this seems to me a misapplication of legitimate deductions from very important data, for such a degree of pliancy seems entirely inconsistent with the maintenance of the continents even on the basis of complete vertical isostasy, as will appear from later considerations, for any type of isostasy that is consistent with the existence of the continents and basins as they are *involves great lateral unbalanced stresses.*

The protuberance of the continents and their repeated rejuvenations when worn down can only be explained, it would seem, on the supposition that the mean specific gravity of the continents is lighter than that of the suboceanic segments. This is the postulate of isostasy. Pendulum observations confirm it. It is common ground where many views meet

Now the continents are always being denuded by the mechanical action of wind, water and gravity on the surface, and by the solvent action of water reaching to notable depths. The protuberances are not only being cut away, but are being leached all the time. There is no real weighting of the continent as a whole under normal conditions. The only apparent weighting is due to the sediments that lodge on it. These are gathered chiefly about the edges, and the weighting here is only a fraction of what is removed from the continent as a whole. The continent as such is being constantly lightened, and if it was in previous equilibrium its constant tendency is to rise. If it can be supposed to have been previously lifted beyond the point of equilibrium it would first be reduced to equilibrium, after which rise would follow. The most that is to be rationally assigned to the weight of sediments on the continental borders is a downward bending while the adjacent land surface rises under denudation, involving a local tilting of the surface toward the sea. The mechanism thus pictured offers no good ground for the explanation of a great sea transgression. That the normal tendency of the continents is to rise, and has been so throughout geologic history, is attested by their continued existence in spite of the constant removal of their material, as also by their periodic rejuvenation and by the continuity of the land life since it began its record. If effective subsidence had habitually cooperated with denudation the disappearance of the continents would have been inevitable. The process of subsidence is not therefore normal to the continents. (Subsidence is of course here used in the conventional sense, subsidence relative to the mean earth-surface. The mean surface itself may of course approach the centre without affecting this relation.) Local or regional subsidence occasionally takes place, but for the continents it is exceptional rather than normal. Apparent subsidence is a common , nomenon arising from the filling of the oceanic basins and the lifting of the sea-level. Local subsidence as one of the features of warping and faulting is of course presumed to be nearly as common as the warping . . . hat is of course connected with a complementary uplift. Subsidences . . . ese local types are not tributary to the parallelism and wide extension . . . he great marine deposits nor to the life adaptations of the great trans- gr . . . ive seas. The consistent elucidation of these forms the supreme problem of the Paleozoic seas.

There seem, therefore, to be very cogent reasons for abandoning the traditional view that the systematic sedimentations and the systematic evolutions of faunas of the higher order are to be assigned directly to vertical or epeirogenic movements of the earth's crust.

We have been considering merely the vertical movements assignable to loading and unloading which might seem to be adjustable to sedimentation so as to promote shelf formation and shelf-life, but we seem to find them incompetent. We had previously set aside deformations springing from internal sources because they are independent and non-adjustable in their nature and are not adapted to give the kind of results the problem requires.

It is still necessary to consider the differential stresses that inevitably arise *within* the continents from their own protrusion. These would arise even if the continents were in perfect isostatic equilibrium with the sub-oceanic segments, in the sense in which the term isostasy is commonly used, i.e. the equal balancing of the pressures of column against column. Strictly complete isostasy in the sense of equal pressures in all directions is only predicable of perfect fluids. If the earth were ever in a molten state, it would undoubtedly have assumed a nearly perfect isostatic state of this higher order, with a closely concentric arrangement of specific gravities and with a universal ocean of uniform depth, as logically pictured by our forefathers. How it could ever have passed from that supposed systematic arrangement to the present high reliefs and to the deep differentiations of specific gravity now being demonstrated, has never been explained satisfactorily and seems inexplicable.

But taking the existing facts of continental protrusion and of deep differentiation of specific gravities, there arises necessarily within the continents lateral stress growing out of their own weight, which is supported at the sides only by the coherency of the mass itself. Reckoned in simple hydrostatic terms these lateral stresses range from 10,000 to 20,000 or 30,000 pounds to the square inch. The coherency of the mass is abetted in sustaining these high stresses by the low slope of the sides of the continents. These stresses are differential or unbalanced, and have a qualitative effect on the crystals of the continental mass similar to that of like stresses on the ice crystals of glacial masses, whatever may be the relative quantitative effect. There is, therefore, an inherent tendency for the continents to creep laterally as do continental glaciers. Both are crystalline masses subject to melting or solution at the minute points where unbalanced pressure becomes intense enough. The transfer of this minute melt or solute to adjacent points of less stress induces return to the solid state, while the point of intensest stress is shifted. So, by indefinite repetitions general movement is effected. While this is conveniently called flow, the mass, as such, remains an effective solid.[1]

The theoretical grounds for postulating continental creep are clear and strong qualitatively, but there is as yet no demonstration of their quantitative value. This is yet to be adjudicated. When sufficient time shall have elapsed and suitable geodetic measurements have been repeated at long intervals, a positive determination should be reached. Meanwhile it is for every geologist to decide for himself how well the hypothesis of glacier-like creep fits the phenomena of slow surface motions, as well as the phenomena of crevice formation, normal faulting, seismic strains and slips, and their kin. Local creep is shown in mines, canyons and elsewhere. The wide prevalence of strains in the outer part of the earth and their sudden relief in earthquake slips seem to be phenomena that might arise from creep, for the strains are constantly accumulating and being relieved; the breaks and slips are not unlike those of glacial crevassing. Other sources of these strains are perhaps assignable.

It is not to be overlooked that creep is quite independent of the ordinary forms of diastrophism, except that its conditions are derived from them, and that even if the continents be in complete isostatic equilibrium in the usual sense of the term, or if they be supposed to rest on inflexible bases, internal lateral unbalanced stresses must arise from the weight of the protruding mass.

[1] CHAMBERLIN, *A Contribution to the Theory of Glacial Motion*; Univ. of Chicago Decennial Publications, 1904.

VAN HISE, *A Treatise on Metamorphism*; Monogr. XLVII, U. S. Geol. Surv., 1904, pp. 47-49, 202.

JOHN JOHNSON, Am. Jour. Sci. (Ed. T. C. C.)

See also CHAMBERLIN, *The Fault Problem*; Econ. Geol., Vol. II, No. 6 and No. 7, 1907.

Such glacier-like creep of the continents, if it is appreciable, is a very slightly descending, essentially horizontal movement in its mean expression, but is naturally subject to some undulation due to internal and basal inequalities much as is the case in glacial creep. Now a movement with so low a slope would push the borders of the continents out on lines nearly parallel to the slope of the sea-shelves and so would only slightly disturb their adjustment to the sea-surface. The movement would thus coöperate with, rather than disturb, the agencies that work to produce broad horizontal sheets of sediments. Such a creep movement is in working contrast with vertical movements which tend to disrupt or warp horizontal deposits.

Such a creep movement should tend to flatten the continent and subdue its embossments, moulding the whole toward horizontality. In this it would coöperate with base-leveling; indeed, it would be in itself a form of base-leveling.

Such a creep, if effective, must cause the encroachment of the continental borders on the oceanic basins, must reduce their capacity, raise the sea-level and to that extent aid in its advance on the land, in this again acting in harmony with the gradational agencies. It is indeed to be reckoned a gradational process, transporting matter from higher to lower levels, as do the land waters. The two agencies belong to the same genus. Ordinary diastrophism falls into the contrasted class whose operations are transverse to the gradational, and so we repeat, ordinary diastrophism disrupts the steady progress of water gradation and creep gradation and nullifies their results.

If the tenor of these considerations is accepted and applied consistently, it lends emphasis to the conclusion that diastrophism, far from being a coöperative agency fitted to promote broad, regular, serial stratification, such as distinguishes the mid-stages of the periods of the Paleozoic, is an inimical agency. As such it must remain in abeyance, if systematic stratification of the pronouncedly broad, horizontal type is to reach its highest expressions.

That this is true will appear all the more clear if we now turn to a consideration of the processes of base-leveling, shelf-cutting and shelf-building, and take note of the conditions that give them their highest expressions.

The mature evolution of the sea-shelf is but the last phase of the joint work of base-leveling on land, terrace-building under the sea-surface and cliff-cutting at the edge of the continent. Planation cuts down the protruding upland, the sea-edge gnaws at the land-borders and advances the shore, while the débris of both processes builds seaward the submerged shelf. All is automatically adjusted to the sea-level. As the work thus advances both landward and seaward simultaneously, it constantly works out its own further adjustments as need of these arises. The slow, partial filling of the sea lifts the water level, aids the landward progress and makes room for new depositions on the surface of the submerged shelf. Given sufficient time without disturbance, the process will inevitably reduce the whole summit of the continent to a plain and submerge it beneath the shelf-sea. It is the supreme process of grand terracing; it lacks only time and a stationary state of the earth-body to reach its ulterior effect, the complete cutting down of the continents to the limit of erosive action beneath the shelf-seas, save as organic growths may offset marine erosion, in other words, the reduction of the whole continental surface to a single terrace-top, covered by a single shelf-sea.

Such a stationary state of the earth-body has, however, never been prolonged to this extent in the known history of the globe. The continuity of land and of land life has been maintained by the rejuvenation of the continents. To this let us now turn.

The critical phase of the problem here—and it is one of the highest moment—hangs on the answer to the basal question: Is the deformation of the earth-body a *continuous* process, working steadily and slowly all the time, or, is it a *periodic* process, acting at times and quiescent between those times? Theoretically this is bound up in the even more fundamental question: *Is the earth-body essentially a viscous or plastic amorphous body, however high its viscosity*, or, *Is the earth essentially an aggregate of crystals and possessed of the elastico-rigid properties of a crystalline mass*: In the one case, its deformative movements are no doubt of the viscous type, continuous and perpetual so long as inequalities of stresses continue to arise; in the other case, the stresses must accumulate with little apparent effect until the effective elastic limit of the crystalline aggregate is reached, when movement will be inaugurated and the stresses eased. Quiescence may then be expected to ensue and continue until the elastic limit is again reached. Continuity of deformative motion is the normal expression of the one constitution; periodicity of the deformative action is the normal expression of the other constitution.

That both classes of substances enter into the constitution of the earth goes without the saying; the vital question is which class so far predominates as to control the earth's working habit. So far as direct observation goes, the crystalline element vastly preponderates. It is little more than an inherited hypothesis that leads any one to replace the dominance of the observed part with a hypothetical viscous substratum, for as we descend toward the heart of the earth the increase of balanced pressure tends to increase the rigidity. So far as the trends of recent progress in the related sciences bear on this question they favour with singular unanimity an elastico-rigid constitution of the earth-body. Such a constitution favours a static condition of the earth-mass, save when accumulated stresses exceed the effective elastic limit of the earth-body and force a readjustment.

The strongest testimony to quiescent periods, however, lies in the very phenomena with which we are dealing, base-leveling, shelf-building, cosmopolitan stratification and cosmopolitan faunas, the climacteric phenomena of the Paleozoic seas.

It becomes clear on thoughtful consideration that close approach to a base-level of wide prevalence is impossible if effective diastrophism is in continuous progress, for diastrophism is inherently hostile to mature planation. If the earth-body is constantly warping in an effective degree, the slow process of planation is constantly thwarted in its work. The narrow range to which the conjoint work of the sea-shelf agencies are confined, compared with the large vertical range through which the surface is commonly warped, even in a short diastrophic period, gives emphasis to this point.

The systematic evolution of a continent under continuous diastrophism is easily followed if we accept the fundamenta' iew that the mean specific gravity of the continents is lower than that of the sub-oceanic segments, and that the degree of isostatic equilibrium that obtains between the continents and the sub-oceanic segments is due to their differences of specific gravity—a view that seems now scarcely [illegible] to question. Whether the diastrophism is actuate' by internal cha[illegible]s, shrinkage or otherwise, or by the transfer of matter and energy from below to the surface, or by the transfer of matter from higher to lower levels on the surface, or by all combined, as is the real case, the equilibrium, or the trend toward equilibrium that springs from the distribution of specific gravities permeates all and gives shape to the deformation in accordance with mechanical laws. The convex lighter portions and the concave heavier portions deform inevitably in a certain general way. This is made the more certain in the earth-habit by the constant unloading of the lighter convex portions and the constant loading of the heavier concave portions. The rejuvenation of the continents throughout geologic history testifies to this and furnishes the observational evidence of the persistence and dominance of the process. This must hold true whether the process be continuous or periodic.

Now if the process be continuous in a marked sense, such, for example, as is implied by the nearly perfect maintenance of isostatic equilibrium between the oceanic and continental segments and also between their larger parts among themselves, the evolution of a continent may be followed with logical firmness. The continent must rise as it is unloaded and [illegible] ocean basins as they are loaded must sink, while a secondary result is [illegible]unter movement of the heavier segments pushing beneath the lighter segments. All this would be completed so quickly as to be catastrophic if perfect fluidity, the condition of perfect isostasy, were suddenly imparted to the whole mass of the earth. If a distinctly viscous condition were substituted for that of fluidity the process would be slower but none the less inevitable. With high viscosity the process might be greatly delayed but should follow the same lines. The most protuberant portions of the continents are most eroded in general and suffer most from transportation; hence they are most lightened, and therefore most elevated in the isostatic process. The continent automatically reproduces itself and must continue to do so until the actuating agency, the primitive differences in specific gravity, is removed by equalization in a manner closely analogous in its final results to the liquid process so easily followed in imagination. Indeed, the process either is a fluidal or a quasi-fluidal process, the mobilities that arise from fracturing and weathering and from the various actions of the fluids external to the earth and from those developed sporadically within it doing slowly and by piecemeal what pervasive fluidity would do promptly.

Now, it seems clear upon consideration that this quasi-fluidal process, or continuous diastrophism in any clear and distinct form, must in its nature constantly disturb and thwart the base-leveling process, for under its action the base-plane must be constantly warping. A prolonged fixity of the base-plane is an obvious prerequisite to effective base-leveling. In proportion as the base-leveling process approaches maturity this prerequisite becomes the more imperative, for the late stages proceed with exceptional slowness. It seems necessary, therefore, either to abandon the doctrine of base-leveling or to reject the doctrine of continuous diastrophism. The observational evidence of base-leveling seems to me much too firm to be put in serious question. The firmness of its observational support seems likely to be greatly increased by the geomorphic studies of the future.

The conditions required for the formation of great sheets of limestone spread broadly over great areas and carrying shallow-water faunas are very closely analogous to those that are imperative for effective base-leveling. In mid-Silurian times coral reefs and a rich shallow-water fauna occupied a notable area in the heart of the American continent. They gave rise to a thick terrane of magnesian limestone in which also breccias and other evidences of shallow water confirm the testimony of the fauna. This terrane, carrying the same or closely allied shallow-water types, not only stretches widely eastward, southward and westward from the coral reefs, but on the north reaches the Arctic islands and north Greenland, and is probably continuous thence to northern Europe, for like types of fossils, coralline and otherwise—some of them peculiar forms—appear in the Baltic region and elsewhere. Closely analogous terranes and faunas are found in the far Orient and in Australia. The close parallelism of sea-surface and sea-bottom that made cosmopolitanism of life of this type possible carries much the same force as a base-plane of like extent; if, indeed, it is not to be interpreted specifically as the marine phase of a protracted base-leveling process.

The absence of much land-wash in the broad shallow seas of this type during the formation of the great limestone terranes seems to imply that the adjacent surface was low and protected from wash by its nearness to the base-level. Otherwise it is not easy to find an explanation of the singular clarity of these seas, for their waters were well agitated as the breccia zones and reefs testify. It was a common tenet of our geologic forebears that limestones were the products of deep seas lying well off shore, where clear waters prevailed because of the distance from the land, but this class of limestones demonstrate by their own physical and faunal characteristics that they were formed in shallow water, well agitated, and not unfrequently close to shore. The widely spread conglomerates, sandstones and shales of shallow-water type lying parallel to the limestones above and below add the force of their confirmatory testimony. All these, interpreted as the products of shelf-seas, seem to require for rational interpretation a long, essentially static condition of the earth-body.

Logically we should now turn from the periods of quiescence of which evidence is found in base-levelings, shelf-buildings, shallow-water terranes and cosmopolitan faunas to the periods of diastrophism that put an end to them, evidence of which is found in orogenic and other deformative movements.

The recurrence of shelf-seas of the higher order are regarded as the work of long lapses of time intervening between the diastrophic interruptions that deform the shelves and draw off the water into the great basins. It has been pointed out earlier that the normal effect of diastrophic action is to depress the existing sags and bow up the existing swells, particularly as the one has been increasing its load while the other has been lightened by erosion. The deeper depression of the sags increases the capacity of the basins. The epochs of diastrophism are therefore held not only to mark off the periods of shelf-sea work but to be an essential factor in causing the recurrence of sea transgression and sea withdrawal.

It is of critical importance, therefore, to learn from the record whether or n diastrophism has taken place at periodic epochs with quiescent intervals between, whether these epochs were relatively short and the intervals relatively long, whether the recurrences were sufficiently regular and definite to have value in fixing time divisions and structural systems and what were the relations of these epochs of diastrophism to the biological and stratigraphical evolutions that are the characteristic elements of the geological systems now recognized.

The limits necessarily placed on this discussion preclude a fair statement of even the partial data thus far gathered. The presentation of this must be deferred. We should note that strict correspondence with the geological systems now recognized is not a decisive criterion, for these systems are not wholly satisfactory. There is reason to think that an ideal criterion would modify these systems in some important respects. New criteria must not, therefore, be judged solely by their concordance with established systems. Certain divergencies may be but signs of superiority. At the same time, there is a fair presumption that the natural groupings of the events of earth-history have been recognized by the geologists of the past. The leading divisions are no doubt true divisions, and should in general fall happily in with the divisions marked by the new criteria, if these are true criteria. The correspondences so far worked out harmonize well with these expectations. It need scarcely be urged that the warped condition of strata and the unconformities that arise from diastrophic movements are better physical criteria for detecting systems and periods than usually occur in undisturbed strata.

It remains to consider the value of diastrophic criteria relative to paleontological criteria. To forestall misconception, let us hasten to note that we are not here seeking criteria of *contemporaneity*, however helpful these may be incidentally, but the criteria *that best mark the beginning and ending of historic periods*. Certain fossils of free and wide distribution, graptolites for instance, mark the contemporaneity of widely separated formations with an accuracy and p[illegible]n that leaves little to be desired, but they have no such peculiar value in marking off great historic periods. In general the two classes of criteria should give a concurrent verdict, but they are not likely to be precisely coincident. In the nature of the case, the end of one period and the beginning of another is placed earlier by diastrophic criteria than by paleontologic criteria, for many of the paleontological effects follow the diastrophic change of conditions as their cause, while paleontologic developments have no appreciable influence on diastrophic events.

It is clear that the major deformative movements condition and are fundamental to both stratigraphic procedure and life evolution. Sea transgression and sea withdrawal profoundly affect marine life, especially that portion most available for historic use. If the great features of renewed diastrophism are the further depression of the great basins and the further elevation of the great embossments in accordance with simple mechanical principles, the common oceanic body correlates the irregularities of these, so far as the basins are concerned, and gives a working mean in the form of the sea-level available on the coasts of all lands. It is not essential that the periodic movements be equable in all quarters to give an equated effect; that is secured by the ocean-body. Periodic movements may thus vary widely in the intensity of their effects in different quarters of the globe without nullifying the universal periodicity of the shelf-sea work and all that goes with it.

The independent and fundamental nature of diastrophism, together with this inevitable equation of the most vital working agency, gives to diastrophism special claims to precedence, if it has good working qualities in other respects. It should have weight as a factor in any case.

From the philosophical point of view, the beginning of an important diastrophic movement is entitled to be regarded as the initiation of a new period, since its normal sequences are a new attitude of the sea-level, a new régime of erosion and deposition and a new phase of biologic evolution. But, at the outset, this is prophetic rather than realized; and however well it satisfies the ideal sense of an initial stage, full of potency, it is feeble in recorded results. It therefore lacks availability as a practical way-mark.

When, however, the special diastrophic movement has been essentially completed and is visibly recorded in disturbed strata, in crustal folds, in unconformities of deposition, in basal conglomerates and in other distinctive marks, its record is especially tangible, definite and lasting, and is withal less subject to differences of interpretation and determination than are most of the signs of a great change in the course of biologic evolution.

While all new phases of evolution are doubtless not due to the influence of environment, physical conditions are so potent that they may be regarded as the dominant agencies in evolution. Other influences are liable to be individual or racial and hence not simultaneous, but a general change of environment, such as follows a change of land-and-sea relations, attended by climatic and other changes, is likely to bring on new phases of evolution in *most or all of the leading life types at the same time.* Individual or merely racial evolutions are not likely to have broad historic importance, while general evolutionary movements imposed by fundamental agencies are likely to have the highest historic importance. Beyond question, such a general change is one of the most obvious credentials of a new period. But if it is a result rather than a cause, and if the cause has well defined characters of its own available as landmarks, the fundamental seems to me entitled to precedence over the sequential.

The superior development of paleontologic data, abetted by inherited views, may for the present incline geologists to look to fossil content for the landmarks of new periods or new systems with more confidence than to the deformative episodes. At first thought common opinion will perhaps regard the former as offering the more precise criteria, but this is open to question. Let it be recalled that it is not the close correlation of distant beds that is at issue but the determination of the beginning of a new order of events. Biologic evolution is very gradual and the rate is not the same for the various orders. It is therefore much a matter of judgment in most cases as to when a new order of biologic events began to take place, if measured by the biologic events themselves. The change of the environment that induced the new events offers, in my judgment, a sharper and better landmark in most cases, so far, fairly tested. The final test must of course lie in a fair and prolonged trial throughout the whole geological column.

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THE DELIMITATION OF THE GEOLOGIC PERIODS ILLUSTRATED BY THE PALEOGEOGRAPHY OF NORTH AMERICA

BY

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INTRODUCTION.

The underlying thought of this contribution is periodicity. There are cycles of earth movement, cycles of sea invasion and land emergence, cycles of erosion and sedimentation, and cycles of organic evolution, all of which are contributory to the elucidation of the earth's chronogenesis. The knowledge of this sequence had its origin in the days of LEHMANN and FÜCHSEL, SMITH, CUVIER and BRONGNIART, but even though the nations have been contributing for more than a century and a half, a great deal still remains to be done before a final, definitely determined geologic time-table showing the natural events in their orderly sequence can be established.

Paleogeography, even though it goes back into the early part of the past century, and even though more than four hundred different maps of this kind have been made, is still in its infancy. Geology and paleontology have now accumulated an abundance of knowledge and there is no more successful method of correlating the scattered observations than by noting them on paleogeographic maps of very limited geologic time. Maps that embrace a great amount of time—the synthetic maps—will not accomplish much, and it is to be hoped that western Europe will soon build rapidly upon the ground work established by SUESS and LAPPARENT.

As the time of the Congress during its meetings at Toronto will be much occupied, the writer concluded to present to it, in printed form and in advance, the argument upon which his paleogeographic maps are based and some of the conclusions resulting from his work. He hopes that these pages will be read by all interested in paleogeography before the maps in illustration of this argument are shown. This procedure is necessary for a clear understanding of the subject, and it is therefore hoped that through this method of presentation much constructive and judicious criticism will be brought out from the members of the Congress.

At the meetings of the Congress, the writer will have projected on the screen a series of maps and charts, which will appear in the order presented on pages 581-582 of this paper. This will be done in order to make his presentation easier of comprehension by the geologists of Europe, who may be unfamiliar with the many American formation names.

The argument will be presented as follows:

PART I. History of the principles of chronologic delimitation.

1. The principles of the older geology.
2. The principles of the newer geology.

PART II. Present methods of chronologic delimitation.

1. The sedimentary method, and cycles of deposition.
2. The paleontologic method.
3. The diastrophic method.
4. The paleogeographic method.

PART III. Illustrations of periodicity and paleogeography.

1. The Siluric period.
2. The Devonic period.
3. The Upper Carbonic-Permic period.
4. The Cincinnatic period.
5. The new geologic time table for North America.

PART I.

HISTORY OF THE PRINCIPLES OF CHRONOLOGIC DELIMITATION.

1. *The principles of the older geology.*

NEUMAYR in his well-known book, *Erdgeschichte*, tells us that the first attempt to classify the sedimentary rocks had its origin in the "formations" of LEHMANN (1756) and FÜCHSEL (1762). Later WERNER (1775-1817) falsely held that these formations were universal for the earth. SMITH of England (1799-1801) was the first to show that formations were characterized by groups of fossils, but it was CUVIER and BRONGNIART (1808-1811) who put this conception into much clearer working order. The former taught that each formation contained its own specially created flora and fauna, and that each creation was in turn destroyed by a general catastrophe. BEAUMONT (1852) explained that these destructions were due to the sudden origin of mountain ranges, and even if this explanation is largely wrong, still it introduced the idea of a physical causation leading to the distinction of the periods (NEUMAYR, 1887, I, pp. 5-7).

NEUMAYR further stated that the formations (=periods) "are not established in nature, because life has been continuous and has developed gradually throughout all time since its appearance. The formations are therefore clearly artificial in character and have been made for the purpose of easy reference and statement. Their delimitation has accordingly been based on the local characteristics of a very small part of the earth's surface; and it is the individual breaks in the marine sedimentation or the changes that have taken place in the distribution of water and land in middle Europe that have fixed the dividing lines between the formations" (1887, II, p. 7).

WILLIS writes that periods are "arbitrary divisions . . . of time and rocks within the eras . . . designed to afford means of approximate designation of the position of any geologic record in the time scale. These should be applied . . . to the volume of stratigraphic evidence as checked by palæontology" (1898, pp. 345-346).

NEUMAYR, however, noted that in his day (1887) a reaction was developing against this artificial delimitation of the periods, and that in several cases it was becoming clear that local changes in the distribution of water and land were not of a restricted character, but were found to occur over very wide areas. For this reason the question was raised whether the changes widely affecting the earth's surface might not lead to a natural delimitation of the formations. On this basis it was expected that the present divisions would be found to be wholly or in part correctly established and applicable to other and more distant regions. The solution of this problem was held to be one of the most important in geology. For current purposes, however, it was thought that what was of most value in this study was not continued research along the lines of the greater groupings, but rather in the smaller and even the smallest divisions, for only after an exact and detailed knowledge of the facts is at hand will a correct and natural classification follow (1887, II, p. 8).

DANA says: "The grander divisions of geological time [as the Paleozoic, Mesozoic, and Cenozoic] should be based, in a comprehensive way, on organic progress, independently of events connected with rock-making and disturbances of the crust. . . . Subordinate divisions [as the periods] should recognize the same criterion, but should depend for their limits, as far as practicable, on physical breaks or events registered in the rock series, and on abrupt transitions in kinds or groups of fossils [not due to local physical causes such as change in depth of water, currents and kinds of sea-bottom]. Since the latter are dependent on physical change, they are a convenient criterion when characterizing large areas" (1895, pp. 404-406).

CREDNER in the eleventh edition of his well-known *Elemente der Geologie* states that the floras and faunas of younger periods are characterized by constantly increasing numbers of species and greater organic improvement and complexity, finally blending into those of the present. Under these circumstances there has always been constant and progressive organic change, and it is this evolution that lies at the basis of period distinctions. Of particular significance for each period is the first appearance of certain more highly organized animals and plants, and at the same time the dominance of other genera and families that have appeared in the previous period but now attain their maximum development, and finally the vanishing of forms that have characterized earlier times (1912, p. 354).

NEWBERRY informs us that "Sir Roderick Murchison, in his description of the Permian of Russia [1845] alludes to the fact that it consists of a trinity of strata—mechanical sediments above and below, separated by a limestone just as in the Trias [of north Europe], which is composed of the Bunter, the Muschelkalk and the Keuper." NEWBERRY in 1860 was, however, the first clearly to direct attention to the "circles of deposition", and in 1874 wrote at greater length on the matter. HULL applied this theory in 1862 to several formations and particularly to the Carboniferous of Great Britain. SUESS (1906, II, pp. 217-218) summarizes HULL's views as follows: "The predominance of the terrigenous, that is clastic, elements carried down from the land should . . . lead us to recognize phases of oscillation of the land, and he thus distinguishes three stages:

Upper stage.	movement . . .	detrital formation.
Middle stage	repose	calcareous formation.
Lower stage	movement	detrital formation."

According to RUTOT and VAN DEN BROECK (1883) a secular oscillation is marked by a complete cycle of sedimentation, consisting of pebbles of submergence, sand and clay, and sand and pebbles of emergence (SUESS, 1906, II, pp. 217-218). On the other hand, the clear-sighted GODWIN-AUSTEN (1872) called attention to the fact that "the marine series is again and again *interrupted*, over large areas, *by continental deposits* [italics mine], like the Old Red sandstone for instance, the Coal-Measures of the Carboniferous system, and the fresh-water deposits of the Weald" (SUESS, 1906, II, p. 277).

As this matter of cycles of sedimentation is of importance and as NEWBERRY is the father of the theory, let us examine his writings more in detail. The Cretacic sequence as seen by him in the country of the Colorado river previous to 1860 led him to "read the history of a submergence of the Triassic continent and an invasion of the sea which resulted, first, in the formation of a widespread sheet of beach sand and gravel [Dakota formation] containing the trunks of trees which had grown on a land surface in the vicinity of the localities where they are found. Second, a mixture of mechanical and organic sediments, constituting the off-shore deposits of the invading sea. Third, a great calcareous mass, the organic sediments of the open sea during the long continued period of greatest submergence "(1874, p. 186).

Later, after a study of the Paleozoic formations of the Mississippi valley, NEWBERRY clearly brought out the idea of periodicity, for he stated that "each of the great Paleozoic systems represented on the eastern half of our continent, may be resolved into a circle of deposits similar in general character to that of the Cretaceous system" (p. 186). These cycles, he held, were caused by "an invasion of the sea and submergence of the land in each geological age, the spread of mechanical sediments formed by shore waves over most of the area invaded; then the deposition on this sheet of mechanical material of a mass of greater or less thickness of calcareous sediments, the record of the quiet occupancy of the submerged area by the open sea; and finally, mixed calcareous and mechanical sediments deposited by the shallowing and retreating sea" (p. 195). "The lines of separation between these [sheets of sediments] are more or less sharply defined according to the rapidity of the submergence, and the nature of the materials acted upon by the shore waves" (p. 193).

"In the foregoing sketch an uninterrupted sequence of phenomena has been alone considered. When, however, during the invasion or recession of the sea, the uniformity of the elevation or depression should be broken and oscillations of level ensue, the record would be considerably complicated, and we should have local alternations of land, shore and sea conditions, which would give us smaller circles [=epochs] within the great ones, and thin sheets of mechanical or organic sediments interstratified in any one of the greater members of the series" (p. 189). "These subordinate circles are proof of oscillations of level, i.e., alternations of shore and sea conditions. It is scarcely necessary to say to a geologist that in passing from the area of permanent land (land that was not submerged in any inundation), to the area of permanent sea (the area beyond the reach of the wash of the land, where neither shore nor off-shore deposits were laid down, but only an unbroken series of limestones), we shall get different sections at different points of observation, the strata becoming more calcareous in one direction, and more siliceous in the other. . . . Local circumstances materially modified the record made by the invasion of the land by the sea. In some places the portion submerged furnished abundant material out of which gravel, sand and clay beds were formed." In other localities little sediment was produced and limestones "were deposited directly upon the clean, washed rocks, with no intervening sea beach" (pp. 195-196).

In the paper from which the above quotations were taken, NEWBERRY offers no explanation as to why the oceans so often invaded the land. However, SUESS in 1885 did not think these invasions were necessarily caused by the movements of the earth's crust as exemplified in the making of great mountain ranges, for, after all, these are comparatively local and culminate rapidly, while the transgressions are far more widely spread and decidedly slower in attaining their climax. There are, therefore, according to him, "independent movements of the sea, that is to say, changes in the form of the hydrosphere" (1906, I, p. 15). He offers no further explanation at this time, but concludes: "It is the physical causes of faunal transformations which will, when once they are recognized, form the only true basis for a delimitation of chronological periods" (I, p. 14).

2. The principles of the newer geology.

In the first volume (1885) of his famous book, *The Face of the Earth*, SUESS asks: "What is a geological formation [=period]? What conditions determine its beginning and its end? How does it happen . . . that these stratigraphical subdivisions extend over the whole globe?" And his answer is: "If we could assemble in one brilliant tribunal the most famous masters of our science, and could lay this question . . . before them, I doubt whether the reply would be unanimous, I do not even know if it would be definite." Nor does one find in the volume an answer to this question, which he finally leaves to "the next generation of investigators" (I, pp. 8, 15).

Previous to 1858 the usual answer had been that each of the larger subdivisions of the geological series was characterized by specially created organic assemblages, each one of which was in turn destroyed by cataclysms. In that year, however, DARWIN stated in his *Origin of Species* that the distinctness of the faunas, separated as they are from one another by cataclysms (=breaks), is explained by "the extreme imperfection of the geological record." With SUESS we agree that the biotic assemblages as known to paleontologists do not as a rule evolve gradually, but "whole groups, entire animal and vegetable populations . . . appear together, and together disappear" (I, p. 11). It is this phenomenon that HERR long ago happily called "the periodical recoinage of organisms," or, as ULRICH puts it, the faunas appear "ready made." In other words, the marine faunas as preserved in the formations are but the momentary organic assemblages of the oceanic areas—the permanent and continuous basins of organic change—spread by periodic transgressions into the sedimentary formations. It is this periodic spreading of the marine waters with their life on which, as SUESS states, "depends the unity of stratigraphical terminology" (I, p. 12). What is true of marine faunas is equally true of land life, for in the continental deposits are seen "the simultaneous appearance and disappearance over vast areas of whole communities, of whole economic unities" (I, p. 13).

It is fortunate that most of our period terms have come from England, not because geologic chronology is more completely recorded there, but rather on account of the recognizable breaks which have "facilitated the conception of natural groups, in a manner which would never have been suggested by other places where one marine deposit regularly follows another" (I, p. 12).

As has been stated in the previous section, NEWBERRY was the first to offer a more or less natural method for the delimitation of the geologic periods through a combination of the physical and faunal characters as recorded in nature. His theory of cycles of erosion and deposition was accepted by POWELL, GILBERT, and DAVIS, through whose combined work recognition was won for the principle "that epochs of marked relief and vigorous erosion have alternated with periods of base-leveling, and that sediments have alternated correspondingly in character and volume (WILLIS, 1910, p. 248).

The detailed application to the American Paleozoic of the principle of sedimentary cycles, it must be admitted, has turned out to be unsatisfactory as a method for the discernment of natural periods of geologic time, but even so we should accord to NEWBERRY the discovery of the fact that the North American continent has been repeatedly invaded by the oceans. In his time and long afterwards, the dominant teaching was that of DANA, which held that the Paleozoic inland sea gradually withdrew from North America, leaving in its wake progressively younger, irregular rings of fossiliferous sediments that had been secreted around the old Laurentian nucleus. The principle of periodic earth movement was thus discovered by NEWBERRY, but the causation underlying it all was still to be elaborated by two other paleontologists, NEUMAYR and, more especially, SUESS.

In the second volume of *The Face of the Earth* (1888), the latter completed a study of the oceans and their more important transgressions throughout geologic time. His views as to the causes underlying these marine spreadings were now matured, and he stated them as follows:

"The theory of secular oscillations of the continents is not competent to explain the repeated inundation and emergence of the land. The changes are much too extensive and too uniform. They have been caused by movements of the earth's crust. . . . In this lies the explanation of the remarkable fact that it has been found possible to employ the same terminology to distinguish the sedimentary formations in all parts of the world. This would have been impossible if the limits of the formations had not been drawn by natural processes simultaneously in operation over the widest areas" (II, p. 540).

In the best known of the periods "the positive phase is of much greater duration than the negative phase which follows it." "Finally, the regular and uniform character of the movements may be recognized from the concordant superposition of the more recent beds on those of much greater age." Often "the stratigraphical relations offer no hint of the great gap which occurs at the line of contact. That this should be the case may well be cause for astonishment, for some degree of erosion, weathering, or other alteration of the surface must have occurred in the interval" (II, pp. 542-543).

"The oceanic regions are filled up slowly but without intermission, and their waters in consequence are gradually displaced; at the same time the transgression which thus results is facilitated by progressive denudation of the land. The formation of sediments causes a continuous, eustatic [*i.e.*, world-wide] positive movement of the strand-line" (p. 543). On the other hand, the local and spasmodic submergences are due to subsidence of the earth's crust.

Lapparent has given much attention to systemic geology and paleogeography. The principles employed in his famous *Traité de Géologie* (1906) follow very much along the lines laid down by Suess, and are thus defined:

"The resources of stratigraphy alone, however precious and indispensable they may be, are insufficient for the establishment of the great divisions of Geology. One must have recourse to something of a more general bearing. This we shall find in the consideration of fossil faunas and floras" (II, p. 717).

"Each formation is the actual representation of what we have called a sedimentary episode, with its phases marked by the different zones. To define this episode completely, one must learn the entire surface distribution of the formation and its boundaries such as they must have been before erosion removed them in part. In a word, it is the restoration of the ancient shores, marine or lacustrine, which, added to the consideration of the thickness of the formation, allows one to appreciate the value of this phase of regional chronology.

"By doing this for the different synchronous formations, one would have a series of paleogeographic maps, whose comparison one with another would permit of recognizing, at a glance, those epochs in which terrestrial geography underwent the most important modifications. Then one could legitimately unite the formations comprehended between two occurrences of this sort, and make of them homogeneous divisions, which one could call stages. . . .

Each stage would correspond to an interval of time to which could be applied the name of epoch.

"Unfortunately the restoration of ancient shores presents great difficulties and there are as yet only a few cases where it has been done with any certainty. So the paleogeographic criterion needs to be corroborated, often even replaced, by the paleontologic method. . . . These [physical] modifications [of the local environment] will bear especially on the species of the littoral zone, and a detailed study of these latter . . . ought to lead to the establishment of divisions entirely in accord with those established on stratigraphic grounds" (II, p. 721).

"However, the stages thus founded on littoral fossils will in general have a too pronounced local character, and if one did not make use of some 'means of control,' it would be difficult, sometimes even impossible, to establish the concordance of paleontologic scales for two distinct regions. The elements of this control will be furnished by the study of the pelagic fossils. . . .

"It is thus that the use of stratigraphy and paleontology combined permits of fixing both the breaks . . . of regional history, and the groupings together, by which it is convenient to reunite local divisions to form groups which can be recognized almost everywhere. . . . In particular one must concede, in the delimitation of stages, a great importance, on one hand to the marine invasions or ingressions (transgressions), shown in the direct transgressive overlap of sediments on the much more ancient lands; and on the other hand to emergences or regressions, which cause the sea to abandon the conquered territory.

"Just as the great variations of regional geography, combined with the alterations of organic content, serve for the establishment of stages, so in the same way the latter can be united into divisions of a higher order, if one takes into account either the geographic phenomena of greater areas, or the appearance or disappearance of characteristic organic groups. We shall give to these divisions the name of systems" (II, p. 722).

Haug is also in harmony with Suess and Lapparent. He states the principles of chronogenetic classification as follows:

"It is on this principle of concordance and discordance that the determination of the age of a system of folds is based. It plays an equally important rôle in stratigraphic studies, for it has led to the theory of cycles, which are greatly concerned in the division of geologic history into periods. Let us recall that a cycle is composed of three successive phases, . . . sedimentation, diastrophism and erosion, which end in the planation of the continents by the action of external dynamic agents. The beginning of a new cycle is marked by a new invasion of the sea over areas previously emergent and transformed into peneplains. This marine invasion is not a continuous phenomenon, it is interrupted by phases of temporary retreat which precede the general emergence" (1907, II, p. 541).

"The migrations of marine animals coincide ordinarily with transgressions, while those of land animals are the result of regressions. One can then say that the changes in the geographic distribution of organisms are regulated primarily by epeirogenic movements. As the oscillations of the different continental areas are synchronous, one understands why certain great renewals of faunas constitute an almost universal phenomenon, and why they furnish so convenient a means of delimiting the great geologic periods" (II, p. 552).

"Each great marine transgression, marking the beginning of a new cycle, coincides with an arrival of cryptogenous types [*i.e.*, the arrival of new genera or new migrants], with a renewal of the marine fauna, and it is thus that the division of geologic time into periods loses more and more its local and arbitrary character and acquires a real philosophic value" (1, p. 21).

CHAMBERLIN (18 8) has well said that "the ulterior basis of classification and nomenclature must be dependent on the existence or absence of natural divisions resulting from simultaneous phases of action of world-wide extent. . . . Great earth movements affect all quarters of the globe" because "in a globe, all of whose parts owe their positions to the stress and tension of other parts, every rearrangement that rises in magnitude above the limits of local support extends its influence to the whole." The movements are not heterogeneous but are periodic, for "the oceanic basins became progressively deeper and more capacious, while the continents became higher (degradation aside). In this assumption . . . there lies, if it be true, a basis for the natural division of geologic events, these movements being in themselves and in their immediate consequences the basis of such division.

"The major movements of the earth's surface have consisted of the sinking of the ocean bottoms and the withdrawal of additional waters into the basins whose capacities were thereby increased." Then, too, the master factor in the great crustal readjustment has been the progressively greater "radial shrinkage of the ocean bottoms" surpassing "the radial shrinkage of the continental platforms to the average amount of some 10,000 or 12,000 feet." Besides these periodic crustal readjustments resulting from internal causes, there are external readjustments of long duration, the quiescent periods, working "to precisely opposite ends, the degradation of the land and the filling of the basins." Due to these causes and others stated by CHAMBERLIN, there has been developed "a succession of shallow sea incursions and withdrawals reciprocating with crustal movements and quiescence . . . from the beginning of the Paleozoic era to the present time. To these features I look for the primary terms [*i.e.*, for eras and periods] of a natural and permanent system of classification and nomenclature" (pp. 449-462).

In 1902 ULRICH and SCHUCHERT, in their paper on seas and barriers, noted the periodic recurrence of marine invasions during Paleozoic time and said: "There is a rhythmic relation between the successive grand subsidences and emergences of the interior of the continent that we believe should be the basis of a revised classification of the rocks of North America. . . . Each system should begin with a subsidence and end with an emergence." Such a classification "will have a natural basis" (1902, pp. 659-660).

Eight years later SCHUCHERT applied more fully the above described principles of the newer geology to the ascertaining of the natural delimitations of the periods. His method was the geographic plotting on paleogeographic maps of the better known geologic faunas of North America and the formations in which they occur. He had then fifty-seven such maps and these indicated that the continent had been more or less widely submerged at least seventeen times since the close of the Proterozoic. The inundations were separated one from the other by an equal number of emergent times. Accordingly it was held that North America had undergone at least seventeen diastrophic cycles and that each cycle represented a natural period of geologic time. In general these diastrophic cycles agreed fairly well with most of the arbitrarily determined periods of the geological textbooks. There was, however, this marked difference, that in the cases of the Cambric and Ordovicic periods, each of these was found to be made up of three cycles, and the Mississippic and Cretacic each fell apart into two, while the Pennsylvanic and Permic periods, so far as North America is concerned, represented but a single cycle. In other words, where the old classification recognized twelve periods and three eras, SCHUCHERT's work appeared to show seventeen cycles of major crustal movement, and that these were naturally grouped into four eras, the Paleozoic being divided into Paleozoic and Neopaleozoic.

In the following year appeared ULRICH's *Revision of the Paleozoic Systems*, a work replete with detailed observations interwoven with much theory. His "strictly consistent" classification of the North American sediments recognizes four eras, of which three are completed (Eopaleozoic, Neopaleozoic and Mesozoic), and each of these has the rhythmic number of four periods. The Cambric, Ordovicic and Mississippic of geologists are each divided into two periods, the Pennsylvanic and Permic are made into one and referred to the Mesozoic, and finally, the Triassic and Jurassic are also united.

In conclusion two other books on paleogeography and paleogeographic methods should be cited: *Die Entwicklung der Kontinente und ihrer Lebewelt*, by ARLDT, published in 1907; and *The Building of the British Isles*, by JUKES-BROWN, which in 1911 appeared in its third edition.

PART II.

PRESENT METHODS OF CHRONOLOGIC DELIMITATION.

1. *The sedimentary method, and cycles of deposition.*

Practice in stratigraphy has long shown that the character of the sediments is not at all reliable in correlating widely separated outcrops, and that even in closely adjacent areas one cannot be certain of synchronous deposition on the basis of petrology alone. "The physical characteristics of rocks are repeated from time to time, and are diverse in different provinces at the same time," says WILLIS. When the age of widely separated deposits has been established on the basis of their contained fossils, the intermediate region can often then be correlated with these standards when the petrologic characters are similar. On the other hand, an identical succession of differing clastic deposits is far more reliable in correlation than the single units, and these, if of considerable thickness, may have wide geographic extension, at least in one direction. Again, limestones and dolomites, when heavy bedded and of considerable thickness, are usually found to recur over a very great area, but when thin bedded and alternating with shales, they may or may not have wide distribution. Oölites are apt to be localized deposits, and are now being formed in very shallow, agitated, warm water seas in proximity to the land, where there is an abundance of denitrifying bacteria precipitating the lime that is in solution and that apparently then accumulates around small detrital particles, crystals, and tiny bubbles issuing from the muddy bottoms (VAUGHAN, 1913, pp. 302-304).

Passage beds or "transition from one kind of sedimentary rock to another . . . even when the change is abrupt, often occurred without discontinuity of deposition. On the contrary, even a 'gradual passage' does not preclude the possibility of a long interruption of the process of sedimentation at such places and times." Interruption is least likely from sandstone to shale or from shale to limestone, and in rare cases there are no breaks from sandstone into limestone. Breaks are most probable between a limestone and a following sandstone and less often from a limestone to a shale, but in the latter case the hiatus is difficult to establish when the formations have scanty or no faunas (ULRICH, 1911, pp. 528-531).

Marine conglomerates of rolled foreign pebbles unmistakably indicate proximity to land on the part of the invading sea, but they cannot be relied upon in correlation, for they are apt to be local in occurrence or tangential in time, *i.e.*, appearing and reappearing at any time during the transgression wherever the environment is proper for their making. They are, however, of much value in directing attention to a probable break in the section, as these conglomerates are generally the initial strata of a transgressing marine deposit.

On the other hand, intraformational conglomerates and "edgewise conglomerates" of thin flat pieces either lying horizontally or standing at all angles except that of normal bedding, rarely if ever have transgressive significance, for they appear to be the result of decided wave action during the time of great storms in shallow seas, when the waves may penetrate with considerable rolling power down to depths as great as 200 feet. Here the pieces are not foreign to the deposit, but are the result of moving and rolling of the soft sea bottom by storm waves. Sometimes entire formations of impure limestones appear to have been thus churned in the course of their deposition, and these are known as knobbly limestones. In such formations there may be an abundance of fossils, but they are usually small and often all immature individuals, alike in the lumps and the darker matrix.

Marine quartz sandstones are also good indicators of shallow seas with decided tidal and wave currents that wash out the muds and transport them elsewhere, and of nearness to land but not necessarily actual shore conditions. It is well known that prevalent winds, through the action of the waves they form, may not only drive the sand upon the beach in dunes, but may also transport it many hundreds of miles along a shore, though as a rule the seaward width of such deposits is not great. The quartz sandstones are the least reliable of the sediments for determining contemporaneity of deposition. They are, however, often of the greatest value in discovering the disconformities or breaks in the sections, and should always be examined for fossils, or the deposits immediately above them should be searched to see if they contain new and different faunas from those below in the sandstone. These coarse materials are often found to be the initial deposits of a transgressive formation, and accordingly may also be transgressive in time or tangential in deposition. Sandstones and even conglomerates of vanishing waters are occasionally seen terminating the formations. On the other hand, thick sandstones without fossils should always be examined to see if they can be of continental origin, either of fresh-water or wind-blown desert or shore dune sands.

Mud deposits make up more than three-fourths of the sedimentary formations and are apt to be the earlier deposits of the invasions; they are also, to a lesser extent, developed during the retreat of the seas. They are apt to be most prevalent and in thickest deposits in those parts of the seas nearest to the lands. Black or carbonaceous muds are at times of very wide distribution and with sparse and uniform faunas, usually of small species which are clearly not bottom dwellers but those derived from the surficial waters. Such faunas are, however, not of general occurrence throughout the shales but are localized in very narrow zones. These black waters are said to have had foul bottoms, not because of depth but because of a lack of oxygen, a condition clearly due to inadequate circulation of normal marine water; such foul places occur in bays, more or less isolated arms of the sea, or eddying regions back of submerged banks or barriers.

Cycles of deposition and erosion.—As described on an earlier page (p. 558) a major cycle of deposition begins with an invasion of the land by the sea, spreading, during the earlier, shallower water phase, more or less coarse mechanical sediments; these are followed by a sheet of calcareous materials, the record of the more open and deeper water stage; finally, during the emerging period of the land, mixed calcareous and mechanical sediments are laid down. Such a cycle of sediments can only form during an early, continuously transgressing phase, succeeded by a long, middle, static period of repose and deeper water, and a final persistently retreating stage. Any one who has carefully noted the geologic formations of any period over wide areas knows that the delimitation of periods can hardly ever be made out on the basis of such assumed cycles of deposition. This is because the invasions do not persist regularly in a given direction, for the lands not only warp but also move differentially during the transgressions, and then the water itself is often oscillatory, causing irregular overflows. Further, the character of the rocks invaded is variable from place to place, while the bordering lands are not only of different elevations but are as well made up of differing rocks that cause the inflowing streams to bring to the sea in localized areas variable sediments in variable quantities. Again, changing climate causes alterations in erosion, while variations in the currents of air and water bring about changes in the sorting of the materials and in their distribution by the sea. The very fact that correlation of formations is not possible through their petrologic character indicates that there are no regularly developed cycles of deposition, and the multitude of formation names continually being coined by the field workers is further attestation of the same fact.

A major cycle of deposition as defined by NEWBERRY probably "never occurred in any continental basin," according to ULRICH. The Siluric in eastern North America comes nearest to fulfilling the requirements for a major cycle, for here the earliest deposits are said to be the Medina sandstone, followed by the Clinton and Rochester shales and impure limestones, and then by the widely spread and thick Niagaran limestones and dolomites of the interior region, when the transgression was at its height, terminating with the emergent Cayugan shales, salt beds, and impure limestones. However, beneath the equivalent of the Medina in the interior of North America are older Siluric deposits, and nearly all of these are limestones or calcareous shales. Then, too, sands and muds are most prevalent in the northern Appalachian trough where the Niagaran limestone is absent, while in the Rocky mountains the cycle of sedimentation is completely at variance with the eastern formations.

The Devonic formations do not at all agree with the requirements of the theoretic cycle In the northern Appalachian trough the period begins with the Helderbergian impure limestones and calcareous shales, followed by the Oriskany sandstone and sandy shales (Esopus), and then by a very thick series of sandy shales and sandstones enduring throughout Middle and Upper Devonic time. In the interior basin the Lower Devonic is absent, while the middle part of the system is represented in the main by limestones, and the Upper Devonic has either black shales or calcareous shales and impure limestones.

We agree with ULRICH that in nature the "great cycles fail so badly that we may well doubt the possibility of using the prevailing conception of cycles of deposition in framing a satisfactory scheme of stratigraphic classification" (1911, p. 315. See pp. 314-317 for complete discussion).

2. The paleontologic method.

It is admitted by all that the primary basis for a geologic chronology is furnished by the organic remains entombed in the sedimentary rocks. All methods for the exact determination of geologic time, and, for that matter, of diastrophic movements as well, are at present primarily dependent upon paleontology and superposition of strata.

A little insight into living marine faunas shows that they differ from place to place, and that while a few species are restricted to a certain locality the greater number have a more or less wide distribution. Many of the sessile and semi-sessile forms are restricted to a definite sedimentary facies, others are not so localized, while the free species have a tendency to an unrestricted facies distribution. A very small percentage of any fauna has a range of several thousand miles, a greater number spread less than one thousand miles, while the majority of any assemblage is limited to less than several hundred miles. Because of this limited distribution, the living organic combinations are grouped into provinces, a limitation first clearly discerned by the brilliant English zoölogist and paleontologist, FORBES, who in 1859 wrote as follows:

A province "is an area within which there is evidence of the special manifestations of the Creative Power; that is to say, within which there have been called into being, the originals, or protoplasts, of animals or plants. These may become mixed up with emigrants from other provinces, even exceeding in their numbers the aborigines, so to call them, of the region to which they have migrated. . . . Provinces, to be understood, must be traced back, like species, to their history and origin in past time. Paleontological research exhibits, beyond question, the phenomenon of provinces in time, as well as provinces in space. Moreover, all our knowledge of organic remains teaches us that species have a definite existence, and a centralization in geological time as well as in geographical space, and that *no species is repeated in time*. The distribution of the individuals of fossil species also indicates their diffusion from some unique point of origin."

The western shore of Europe "I purpose to regard as comprehending six provinces, since within them we can fairly reckon so many distinct centres of creation. The first and northernmost is the Arctic province, extending throughout that portion of the European seas included within the Arctic Circle. The second is the Boreal province, including the seas which wash the shores of Norway, Iceland, the Faroe, and the Shetland Isles. The third is the Celtic province, in which rank the British seas, the Baltic, and the shore of the continent from Bohuslan to the Bay of Biscay. The Lusitanian province includes the Atlantic coasts of the Peninsula. The Mediterranean province speaks its own explanation; the Black sea is included in it. Lastly, the Caspian is a region now completely isolated from all the others" (pp. 6-16).

Provinces of greater geographic extent are those of the shallow waters of the Pacific realm bordering the two Americas. According to DALL (1909) there are here (1) Arctic and (2) Antarctic more or less circumpolar cold water faunas; (3) the Oreganian cool water province extending from Behring sea south to Point Conception, California; (4) the Californian temperate province, south to Lower California; (5) the Panamic tropical province including the Gulf of California south to the Bay of Guayaquil, Ecuador; (6) the Peruvian temperate province (with more than 800 species of mollusks) to southern Chile, and (7) the Magellanic cool water province, embracing the Fuegian archipelago and the Atlantic shore to some undetermined point north on the Argentine coast. It should be added that these provinces are more or less conditioned by temperature and oceanic currents. Temperature as a factor in the sense of to-day was, as a rule, almost absent during the greater part of the geologic past, and yet the extinct organic provinces are as easily discernible by the paleontologist as are those of the present by the biologist.

Next to temperature the most important physical cause for the delimitation of the organic provinces of the present is the land projections or capes, because these land barriers are the deciding deflectors of oceanic currents. Their importance in the overlapping seas of the past is, however, less significant, because so many of these waters occur as shallow extensions or vast bays that are far more extensive than the combined North sea and Baltic sea of the present.

If we wish to know to what extent the living marine shallow water forms are localized, we can readily obtain statistics from the conchologists. Let us take the Peruvian province. According to DALL (1909), the total number of species is about 869, of which 64 are pelagic, leaving 805 that are bottom dwellers. Of these latter, about 40 per cent. (315 species) are restricted to the province, while 54 per cent. extend their range into the adjoining northern and southern areas. The remaining 6 per cent. are very widely distributed species common to at least three provinces (3 per cent.) or also occur in the Atlantic-West Indian region. We may generalize these results by saying that the shallow water bottom life of a province has 40 per cent. or less of its species localized, while at least 60 per cent. are common to two or more provinces. These figures are of especial value to paleontologists, indicating as they do that the majority of any fauna has a more or less wide geographic range, and further, that not more than 13 per cent. are ubiquitous species of little provincial and limited stratigraphic significance. In cold water faunas the percentage of localized species may be even less, while the very widely distributed forms may exceed 20 per cent. Glacial climates, however, are of very rare occurrence throughout geologic time, so that the comparisons of paleontologists must be rather with the biotas of the temperate and warm waters and climates of to-day.

Fossils furnish the first step in the process of stratigraphic correlation and may be depended upon in fixing the boundaries of the major divisions. This is because species and faunas endure a given length of time, from their initial appearance somewhere to their extinction everywhere. Exact correlations are possible not only for the basins of a continent, but likewise for intercontinental areas, though here the inherent difficulties are greater. Even a single or a few species will often indicate such synchronous or homotaxial deposits, but in general successful correlations are dependent upon organic assemblages in greater quantities. This dependence is the result of more than a century of persistent study in many lands of the superposed fossil biotas as determined and recorded by the paleontologists.

In general, sedimentation is a slow process, and by the time one foot of average rock has accumulated probably a thousand generations of marine invertebrates have come and gone. Under a relatively constant environment it is held that but little if any recognizable change in the species will be developed, but the habitats are continually changing, and even though only to a minor extent, still this alteration causes the faunas at least to vary their combinations and to shift from place to place. They die out in one area but get a foothold elsewhere, and although this shifting, or to-and-fro migration, is slow when measured in years, yet in stratigraphy the faunal assemblages appear as if suddenly introduced. This fact has always excited the interest of the paleontologist and he has explained the phenomenon as due to special creations, recoinages, imperfections in the record, shiftings of faunas, or to geologically sudden migrations into the continental seas from the permanent oceanic reservoirs, the continuous seats of organic marine evolution. Certain Middle Ordovicic faunas (Galena) are common to Iowa, Minnesota, and Ellesmereland; Upper Ordovicic (the easily recognized Richmond) from Texas to Alaska, and from Nevada and Wyoming to Quebec; Upper Devonic (Lime Creek) from Arizona to Iowa and western New York. The fossil faunas spread as fast as the sea transgresses the land, and, for practical purposes in stratigraphy, may be accepted as appearing simultaneously in [illegible]ly separated places.

In correlating faunas of widely separated areas, sole reliance cannot be had on a mere matching of some of the species and genera, because there are in all faunas a more or less great percentage of holdovers, static or irregularly evolving forms that are not determinative of exact geologic time. The localized species are of greatest value in the stratigraphy of limited areas; of most significance in correlation are the new forms of wide dispersal, for they are the progressives, the time heralders of their variously conservative associates. Therefore in stratigraphic correlation most dependence is put upon a few species, the proven "guide fossils," supported by the collateral evidence of the associated forms. These guide fossils may be of any class of organisms and are either rare or abundant in individuals. The more abundant they are, the greater is their geographic distribution apt to be, and the more easily do they mark a horizon. On the other hand, the wider the distribution of the guide fossils, the less can they be depended upon for detailed chronology. When these guides have, in addition, easily discerned characters and are individually abundant, then they are of the greatest practical value; such widely ranging guides among the brachiopods are *Productus giganteus, Spirifer cameratus, Stringocephalus burtini, Hypothyris cuboides, Rhynchotrema capax, etc.*

The appearance of identical fossil genera of land animals, and more especially of mammals, in two continents that are now separated is often taken as positive proof of the former connection of the two areas by land bridges that have since vanished. This method of correlation is undoubtedly correct in the main, but as genera apparently alike have been developed from unrelated stocks (parallel development and homoeomorphy), single appearances on two continents cannot be accepted as migrant individuals from a common centre of evolution and dispersion until the phylogeny has been established in each case. In the same way marine invertebrate genera appearing in two or more realms at the same time may also be parallel developments or independent origins from different species of the same genus. Dacqué (1913, p. 204), states that among the ammonites Hoplites-like forms appear in widely separated realms during the latest Jurassic and earliest Cretacic times, and that they have been developed out of different species of Perisphinctes.

Of great value for interprovincial and intercontinental correlation are often the floating and swimming animals. Of these the most serviceable are the graptolites, heteropods and pteropods, the coiled nautilids and ammonids, and the Crustacea. However, their individual value in correlation is very variably exact, and the longest (geologically) enduring forms are found more often among the floaters than among the swimmers. The wide distribution of some of these free forms is at times surprising, and all the more valuable are they when they endured but a short time. Certain Ordovicic graptolites are world-wide in their distribution, and identical ammonids are often found in two or more continents. On the other hand, animals living on the bottom of the seas are also at times of wide distribution, and of such in the order of their chronogenetic value may be mentioned bryozoans, brachiopods, and corals. The distribution of this benthos is conditioned not wholly by the water currents, but as well by an abundance of larvæ that have a protracted or slow development before they sink to the bottom and become sessile in habit. Such slowly developing larvæ are not, however, common in cold waters.

Locally superposed but distinct geologic faunas derived from the same oceanic realm have usually a more or less direct genetic relationship with one another. In some cases they are returning, slightly altered faunas, in other words, recurrent faunas. Therefore, a possible depositional break between such superposed faunas is easily overlooked and the time value of the recurrent faunas underestimated. On the other hand, two locally successive faunas may be totally dissimilar, not only in the species but even in the majority of the genera, and yet the time break between them may be a comparatively short one. The reason for this is that the two faunas are transgressions from different oceanic realms, a condition most common in the Ordovicic and progressively less so in the Siluric and Devonic of North America.

Contemporaneous faunas in closely adjacent areas may be widely dissimilar, due to separating barriers that, in the shallow seas of the North American continent, are apt to be unsubmerged, narrow lands. The transgressions from two oceanic realms attain the barrier but maintain their faunal distinctness. Their synchroneity is not then easily determined alone on the basis of the faunas, but is ascertained through subsequent overlapping of the barrier, when interchange between the two provincial faunas takes place.

The various faunal provinces of a continent are most alike in composition and have the greatest number of species in common, *i.e.*, are most cosmopolitan, during the middle age of the periods or during the times of widest marine transgressions. This is due to overtopping of the lowest places in the land barriers, when the invasions are highest and the lands lowest, and there is an interchange of waters and faunas. On the other hand, synchronous faunas are most dissimilar in the early times of the periods, when the oceanic realms are most localized and the marine shallow water provinces are smallest, due to the narrowness of the continental shelves at these times of greatest continental emergence. Similar faunal restriction also takes place during the closing times of the periods, due to the same physical causes, but at these times there are many more holdovers from the earlier, widely dispersed faunas. In other words, there is no marked introduction of new organic types during the recession of the continental seas. However, when the oceans again begin to spread over the continents, a long time has elapsed, many of the old familiar forms have disappeared, and new forms, the cryptogenous species of HAUG, have been developed—the heralders of a new period and prophets of the next trend in evolution.

An analysis of the Paleozoic faunas of North America clearly shows that this life was derived from three permanent oceanic realms. In the order of their persistence, these are: (1) the Gulf of Mexico mediterranean, which is in reality but the southern part of the northern Atlantic (or Poseidon), while the northern part of the same realm is the least transgressive of all; (2) the Pacific; and (3) the Arctic. The faunas of northern Poseidon, with north European affinities, are as a rule restricted to Acadia and to the northeastern portion of the Appalachian troughs, yet they frequently spread across these barriers and mix with the life of the interior basin area. Those of the Pacific spread at times completely across the continent to the foot of Appalachia. The Arctic waters pulsated south along the medial region of the continent far into the United States during the Ordovicic and Siluric and less positively at other times. From the Gulf of Mexico the transgressions were by far the most common and spread far throughout the Mississippi valley and the Appalachian area of the United States. Then, too, these Gulf faunas were often tinged with south European forms, but at times were related to those of South America.

3. *The diastrophic method.*

On earlier pages have been presented the views of SUESS, NEWBERRY, CHAMBERLIN, LAPPARENT and HAUG relating to the character and significance of the periodic movements or deformations of the earth's surface. The processes underlying crustal movements of any character whatever are embraced under the term *diastrophism*. CHAMBERLIN, WILLIS and ULRICH have made this field of geologic study in America especially their own.

The writer is here not concerned with the theories as to the reasons why the earth changes in form, but only with the surficial effects resulting from the movements that remold the land surfaces and change the oceanic hollows. It is these movements that cause the oceanic strand-lines to shift back and forth over the continents, resulting in continental submergences and emergences, a diastrophic action that underlies a natural chronogenetic classification of geologic events.

Very few geologists now believe in the Lyellian teaching that all parts of the ocean bottoms have been land; on the contrary most of them follow

DANA in the conclusion that the ocean basins have been practically permanent. WILLIS says the latter "are permanent features of the earth's surface and they have existed, where they now are, with moderate changes of outline, since the waters first gathered" (1910, p. 243). The proof that there is no complete interchange between the continents and oceans is seen in the facts (1) that upon the continents there are almost no deep-sea deposits; (2) that the sediments of the periodic oceanic overlaps upon the continents are in the main those of very shallow seas, while the entombed life is all that of shallow water and is at best but a very imperfect record of the continuously evolving life of the oceanic basins; and (3) that the submarine masses are denser than the lands, making it impossible for them to have interchanged their positions without recording it in the continents, and, as WILLIS says, "there is neither evidence nor explanation of such a change."

On the other hand, deep troughs, or the geosynclines of DANA, have been repeatedly developed within the continental plateaus, *i.e.*, are intercontinental, but even though some of them have in places subsided to over 10,000 feet, yet at no time have they, on the evidence of their sediments, been other than very shallow seas. This is certainly true for the Appalachian and Cordilleran geosynclines. "The history of a geosyncline comprises a prolonged stage of subsidence accompanied by a more or less constant deposit of terrigenous or marine sediment, and often a further stage of compression, folding of strata and elevation as a mountain range" (WILLIS, 1910, p. 213).

The North American continent is known to be made up of heterogeneous elements that have largely been of that nature throughout geologic time. "Heterogeneity may also be an effect of terrestrial forces acting, as by intrusion, to modify the original structure. . . . The distinction between the continental elements is based upon their behavior during vertical movements. . . . those continental elements which have tended to rise [the positive continental elements of lighter density] are recognized by the unconformities or absence of sediments resulting from conditions of erosion, whereas those elements that have tended to sink [the negative continental elements of somewhat heavier material] are recognized by the accumulation of sediments upon them" (WILLIS, 1907, p. 390).

Recalling that "coast lines are established along the monoclinal flexure which joins a rising with a sinking continental element, and that sediments accumulate to greatest thicknesses usually in a zone parallel to the coast [the geosynclines], we see that zones of folding are commonly coastal zones. . . . The Leitlinien of SUESS constitute criteria for the analysis of continental structure which are scarcely second in importance to unconformities and deposits." These lines are due to the effects of tangential pressure acting from the Atlantic and Pacific sides, pressures that proceed from the denser submarine masses and "are due to what may be called *suboceanic spread*" (ibid, pp. 391-392).

As shifting of the strand-line is the most important criterion in ascertaining diastrophic action, it is well to state here how these alterations are most readily ascertained. Organically they are recorded "(1) by abrupt changes in the aspect of faunas, and (2) by the sudden appearance or reappearance of species and genera in deposits of continental seas"; physically, "(1) by more or less obvious breaks and hiatuses in the stratigraphic column, indicating sea withdrawals, (2) by changes in the character of deposits, especially when this involves abrupt transition from biochemical and organic sedimentation to clastics, or a change from land to marine deposition, and (3) by overlaps of marine sediments" (ULRICH, 1911, p. 411).

The sea periodically moves over the land and with it the evolving fauna of the time which *pari passu* is entombed in the depositing sediments, and when the waters recede into the oceanic basins then the floras and faunas of the land attain great areal increase, so that the preserved organisms of any time will permit exact interpretation of the ever changing strand-line. On the other hand, correlation of formations on the basis of unconformities and changing petrology is far less reliable and must ever remain second in importance to the biotas for the discernment of diastrophic action. Of course the most easily determined crustal movements are those leading up to the "critical periods," not only because of their usual angular unconformities, but as well on account of the very marked organic differences on either side of the lines separating the eras, lines representing "lost intervals" of considerable magnitude.

These "lost intervals" are known to be many, but they are far more in number and their time duration, although admittedly very variable, is far greater than is usually believed to be the case. The geologic column will probably never be completed on the basis of the recoverable physical record, but it will grow into greater perfection for a long time to come. This growth will take place by the recovery of formation after formation along the lines of these lost intervals, and more particularly in the areas nearest to the continental margins. The perfection of the column will bring about a greater harmony in the very variable estimates as to the age of the earth as given on the one hand by the geologists and on the other by the physicists. However, that these lost intervals and all other imperfections of the geologic record can together be of the magnitude of from five to ten times greater than the present commonly accepted estimate of the age of the earth by geologists seems hardly probable, and yet the calculations based on radium disintegration, according to the physicists, give the age as not less than 750,000,000 years.

The first stratigrapher to emphasize strongly the presence of many and marked "breaks" in the Paleozoic succession of strata and faunas was Professor A. C. RAMSAY in his Presidential Address entitled, *Breaks in succession of the British Palæozoic strata*, delivered before the Geological Society of London on February 20th, 1863.

"By *breaks in succession*," RAMSAY says, "I understand those physical interruptions in stratification marked by the unconformity of an upper formation to one immediately underlying it, or, when such visible unconformity is wanting [=disconformity], by a sudden change in the fossils characteristic of the underlying and overlying formations" (1863, p. xxxvi). He then describes ten decided breaks or "lost epochs" in the Paleozoic succession, and although a conservative geologist, with a "long personal knowledge of phenomena in the field," he concludes as follows:—

"Believing that the causes that produced physical changes were much the same in former times as now, both in kind and intensity (speaking generally, when spread over long epochs), *then the upheaving, contorting, and dislocation of the strata, and the vast denudations they underwent before resubmergence, generally represents a period of time longer than that occupied respectively by the deposition of the formation disturbed, or of that which overlies it unconformably.*

"In the present state of knowledge these things cannot be proved, but we may strongly suspect them to be probably true; and if they are so, then it follows that *the periods of time stratigraphically unrepresented during the Palæozoic epoch were much longer than those of which the various formations of that epoch bear witness*" (1863, p. lii).

In the following year RAMSAY returns to the same subject in his second presidential address, *The breaks in succession of the British Mesozoic strata.* Here he cautions against the frequent assumption that even a formation like the Lower Lias is complete; "and if of the Lower Lias, far more so of the entire Lias series; and stronger still is the warning that may be drawn from such phenomena against the supposed completeness of the Oolitic formations. Conformities are often *accidental*, and amid the obscurities of the Lower Lias plains of England they may well be deceptive; in the Oolitic series we have seen that they are so."

"Making, as we can often do, all liberal allowances for diversities of marine and terrestrial conditions, I cannot resist the general inference that, *in cases of superposition, in proportion as the species are more or less continuous, that is to say, as the break in life is partial or complete, first in the species, but more importantly in the loss of old and the appearance of new allied or unallied genera, so was the interval of time shorter or longer that elapsed between the close of the lower and the commencement of the upper formation;* and so it often happens that strata a few yards in thickness, or, more notably still, *the absence of these strata*, may serve to indicate a period of time as great as the vast accumulations of the whole Silurian series" (1864, p. lx).

The study of the Jurassic formations of western Europe, because of their extremely varied and abundant faunas, has given rise not only to many paleontologists, but as well to many contributions to stratigraphy, and has led to the discernment of many breaks of varying importance. It was in the Lias and Oolites of England that stratigraphy began with WILLIAM SMITH, and on the continent these faunas attracted the attention of many paleontologists, among whom are especially to be mentioned VON BUCH, DUFRENOY, ÉLIE DE BEAUMONT, QUENSTEDT, D'ORBIGNY, OPPEL, MARCOU, and NEUMAYR. In England to-day BUCKMAN is doing telling work in the Jurassic, and in a paper published in 1910 he directs attention to the breaks and to the tenuous beds, elsewhere very thick, in the Lias and Oolite formations of South Dorsetshire. Some of his conclusions are as follows:

"A school boy once defined a net as a series of holes strung together, and the Dorset Inferior Oolite might be defined as a series of gaps united by thin bands of deposit. . . . One can hardly view the few feet of Inferior Oolite limestone at Burton Bradstock, about 15 to 20 feet say, and imagine that it represents an interval of time equal to a quarter or a fifth of the whole Jurassic Period—a time during which thousands of feet of strata were laid down. But this is because we do not allow sufficiently for the gaps. . . .

"The Upper Lias part of the Junction Bed of Down Cliffs, Chideock (Lower or pre-*striatulus* Toarcian), is a very condensed, imperfect epitome in 20 inches of about 180 feet of strata on the Yorkshire coast, and of very much more when allowing for gaps.

"Between the *bifrons* layer and the *striatulus* layer of the Junction Bed there is occasionally a 2-inch layer which is all that represents some 250 feet of deposit in the Cotteswolds—so that about two feet of Junction Bed was formed while a thickness of some 550 feet was being deposited elsewhere" (p. 89).

The first American stratigrapher to emphasize the great abundance and long endurance of these inter-period lost intervals was Ulrich, in his suggestive *Revision*, pages 315-252. He holds that the "time values of the successive periods are not greatly unequal" and that each period is delimited by lost intervals of variable duration, when oceanic spreadings are completely withdrawn from the North American continent to the extent of the present condition of overlap. Most of these intersystemic intervals are unrecoverable because their sedimentary record lies buried beneath the oceans, but the shorter and more numerous intrasystemic intervals will in the main be recovered.

It is well known that land erosion has continually gone on, but that marine sedimentation has been inconstant and may even locally fail to accumulate is not so well known. Andrée (1908, pp. 397-410; 1912, pp. 346-347) has brought together considerable information indicating how sedimentation fails to accumulate in areas of the present seas, due in the main (1) to current action (oceanic streaming and tidal currents), and to a lesser extent to (2) storm waves and (3) chemical solution. Such lacunæ he terms "submarine corrasion breaks." Andrée further cites a number of breaks in the Devonic and Culm of Germany and in the lowest Cretacic of the Alps, which are also thought to be due to current action. Undoubtedly there are stratigraphic lacunæ due to these causes, but in general the writer thinks that our German confrères have given this interpretation too much weight.

Willis (1910, pp. 248-249), points out correctly that in the ocean to-day there are areas where sedimentation is not going on, *i.e.*, there are *intraformation planes of erosion* in the Recent formations, and that, therefore, the evidence of "breaks" in the geologic formations, unless accompanied by the phenomena of erosion, cannot be relied on to prove emergence at the time and place of such hiatuses. We must not fail to note, however, that the areas of non-sedimentation in the oceanic areas of to-day are limited in number. That land erosion in some form has constantly gone on, no one will deny. But where the organic record indicates a marked break between two superposed faunas, why assume that we can-not accept this evidence unless it can be shown that erosion phenomena are also present? As in many of these the faunal breaks are accompanied by the phenomena of erosion, are we not justified in accepting many other similar ones that do not show unmistakable land conditions? It should be further pointed out that these intrasystemic breaks occur most frequently during the times of positive diastrophic action or in the earlier stages of the periods, and least often during the middle epoch of repose. This is just the reverse of what WILLIS postulates in the paper cited (p. 259). Again, it is true that in certain quarters too much stress has been laid upon the sudden petrologic alterations in dircetly superposed strata, but, even so, we shall probably make greater progress by accepting even this evidence as indicative of emergence than by passing it by as not worthy of our interpretation. "Universal seas and universal formations" has had its long day in stratigraphy; now let us be swayed, for a time at least, by the working hypothesis that seas are markedly evanescent, transgressive and regressive, and at times even decidedly oscillatory.

The crustal alterations of the earth are not due to heterogeneous and unrelated movements, but are related, in that areas of elevation and depression remain positive or negative throughout all time or during more or less long periods of geologic time. According to CHAMBERLIN, "Deformations are inheritances, one of which follows another in due dynamical kinship. The succession is therefore homogeneous and the results co-ordinate. . . . Under this view, ocean basins and continental elevations tended toward self-perpetuation" (1910, pp. 288-300). This view ULRICH holds to be true not only for the major segments of the earth but as well "for relatively small portions of each continent. Once started the areas of relative uplift have always [the present writer would state have usually] continued to be areas of stratigraphic overlap or of land, while the relatively depressed areas remained as a rule areas liable to subsequent submergence" (1911, p. 396).

The major crustal deformations are periodic in appearance and their visible areas of movements are now in this continent and now in another, and it is this periodicity that conditions geographic history and organic evolution. Each one of these active and decisive movements is of long duration, and their major work is confined to the marginal areas of the continent. Farther inland new axes or depressed folds may rise or old ones be accentuated, and so divide the continental basins into a series of smaller waterways. Not only are the margins of the continents elevated, but apparently at the same time the oceanic basins are made either deeper or larger or both. This simultaneous movement of the oceanic bottoms and the continental margins is proven by the fact that the major crustal deformations occur during the emergent times of the geologic periods, and this is true not only for the continent deformed, but as well for other land masses that have not moved at all, but whose strand-lines have been lowered in consequence of the oceanic enlargement.

The long enduring middle portion of the periods is marked by relative crustal stability, peneplanation of the continents, and maximum sea invasion on account of more or less of sea filling. On the other hand, the earlier times of each cycle exhibit less crustal constancy and more marked erosion. The lands then warp more or less along predetermined lines, due to compensating internal adjustments following the major movement and to the reëstablishment of the isostatic balance that has been altered by these deformations, by the sea invasion, and by the unloading of protuberant land areas into the loading seas of the continents. During the closing stages of the periods, there is a renewal of crustal unrest, seen in the vanishing of the continental seas, that finally ends in another major crustal movement and in complete withdrawal of the seas from the lands.

There is a certain amount of rhythm in these periodic movements and it is this meter that permits of grouping the formations into systems or periods. The more active orogenic introductory movements are of comparatively short duration, while the quieter epeirogenic, intrasystemic and eustatic movements are of long continuance, and each submergence with the following emergence is seemingly the natural basis for the delimiting of the periods. Among these periodic movements some are far more intense and of greater geographic extent than others, at times when mountain ranges in more than one continent are simultaneously or successively in motion. These are the diastrophic grand cycles, or according to DANA and LE CONTE, the "critical periods" or "revolutions" in the history of the earth, and they bind, as it were, the periods or chapters into the eras. In North America, one of these marked periodic movements in the Appalachian Revolution appeared toward the close of the Coal Measures. Previous to this revolution the Appalachians had been in motion at least three times, but none of these movements had the significance of the one appearing toward the close of the Paleozoic.

4. *The paleogeographic method.*

Paleogeography treats of the ever changing geography of geologic time. It seeks to map the configurations of lands and seas and their relationship to one another; the topography, structure and volcanic activity of the lands, the depths and circulation of the marine waters, and the nature of the varying climates. This constantly changing physical environment reacts on the organic world and causes it to alter in its parts, and as either sediments or organisms or both have at all times been recording themselves in one place or another, it follows that the interpretation of this record will lead not only to a determined paleogeography, but as well, through the study of stratigraphic superposition, to a determined chronogenesis and phylogenesis. The paleogeographer seeks to determine the individual parts of "the great procession of geographies, which has moved down the ages . . . . because paleogeography is thus comprehensive, no one investigator can adequately solve its problems" (WILLIS, 1910, pp. 242-243).

The first guidance in the making of paleogeographic maps is found in the widely accepted postulate that the great ocean basins, in which are also included the Mediterranean, Caribbean and the Gulf of Mexico, are to all intents and purposes permanent features of the earth's surface. But, though the great continents have always been where they now are, their size and shape have not always been constant; some have been enlarged and others have been decreased and added in part to the oceanic areas.

Important papers on paleogeography are by ARLDT (1912, a review of forty-four articles) and by POMPECKJ (1909).

The Appalachian and Cordilleran geosynclines are the natural coastlines for the continental seas of Paleozoic and Mesozoic time, and these guide lines are of the greatest significance in the making of paleogeographic maps.

Having ascertained the significant content of a fauna and its limited stratigraphic position in the geologic column, the next point of greatest value is the deciphering of the probable geographic distribution of the formation containing the biota, or as LAPPARENT states it, the definition of the former distribution of the sedimentary episode. Primary reliance is of course placed on the distribution of the fauna mapped, while the probable shore lines are determined from the geosynclines, the extent and thickness of the formation, and its petrologic, marine, brackish or lacustrine characters.

Of considerable value in deciphering the probable extent of the transgression, whose traces are subsequently covered by other deposits, is the geographic pattern of earlier and later invasions, *i.e.*, the situations of the positive and negative continental elements which remain fairly constant. An analysis of the American Paleozoic formations shows that they occur in greatest number and best development in the periodically sinking negative areas, and that these shallow seas are situated between rising positive regions. The latter are usually the faunal "barriers", the geologic "domes" and "axes" or "parmas," and, in addition, in all such areas are more frequently seen the transgressive "overlaps" of the seas, structural features of the continent most easily overlooked because of their depressed topographic expression. Much assistance is gained in this way throughout the great interior basin of North America, but in the extensive folded and faulted geosynclines of the Appalachian and Cordilleran areas, dependence is for the present almost solely upon the distribution of the faunas.

No one knows better than the writer that paleogeographic maps are not as yet fixed and finally determined. His own err too much on the side of marine restriction because of the loss of formations through erosion and their obscuring through overlap. On the other hand, most of the published maps embrace too much time and often formations that are not correlatives of each other. It is these synthetic maps that undergo marked changes with the increase of knowledge or renewed effort toward more detailed analysis, and the writer is eliminating them as fast as is permitted him. In

1910, he had fifty-seven maps illustrating the geography of North America since the Cambric, and at present the number has risen to eighty-five. Even though the maps are known to be faulty, still, constant effort at greater detail in correlation and the plotting of new stratigraphic data can only lead to greater perfection. The writer does not agree with WILLIS that "there is danger in carrying the refinements too far on the basis of paleontologic correlation alone," although he constantly bears in mind this admonition. The maps in hand make it plain that the North American continent has been repeatedly inundated by the oceans and that the waterways recur in more or less definite patterns throughout each era.

It is unfortunate but at present necessary that all paleogeographic maps must be drawn over the present geography, *i.e.*, the ancient geography is shown over that of the present, which is the result of all past diastrophic action and dynamic work. Therefore, none of our paleogeographic maps can be exact geographic pictures of the past. Then, too, if the earth is a cooling globe and has been shrinking throughout time, it is self-evident that all oceans and lands of the past appear too small on these bases. What this radial shrinkage in the course of time has amounted to, no one knows, but the magnitude of it becomes somewhat apparent if we accept the postulate and calculations made by HEIM on the basis of the Cretacic-Cenozoic foldings of the Alps, amounting to 1000 kilometres (DACQUÉ, 1913, p. 203). Accepting postulates of this nature, all paleogeographic areas of seas and lands of any time must be progressively enlarged as we proceed back into geologic time. Geographic illustration also becomes progressively more inexact the greater the areas depicted, because of the projection of a round body—the earth—upon a plane surface. These matters are more fully set forth by DACQUÉ and it is well to bear such limitations in mind. However, for present purposes paleogeography must be illustrated on the maps of the present geography, but in the course of time greater exactitude can only come about through illustrations on a geoidal model. These limitations, so far as North America is concerned, are probably of less significance than for any other continent of the northern hemisphere, because of the comparatively little crumpling its great interior region has undergone since the close of the Proterozoic. The paleogeography of the vast interior of North America can safely be drawn upon the geography of the present, and the result, for all practical purposes, will give a fairly exact picture of past changes.

PART III.

ILLUSTRATIONS OF PERIODICITY AND PALEOGEOGRAPHY.

The methods described in Part II of this paper have been more or less consistently applied by the writer during the past ten years to the mapping of North American geographies since the Cambric. All of these maps—eighty-five in number—cannot be spread before the Congress, and only such will be projected on the screen as are necessary to bring out the fact that geologic time is clearly divisible into rhythmic periods, each one of which is delimited by a completed diastrophic cycle.

The illustrations will begin with (1) the Siluric and (2) Devonic cycles, because of their remarkably sharp diastrophic development the world over. Then, too, there is now very little disagreement among stratigraphers regarding the boundaries of these systems of formations. Next will be shown (3) a small series of maps which bring out the fact that in North America the Pennsylvanic or Upper Carboniferous is not diastrophically separable from the Permic. The record of this time in America is clearly of but a single cycle, whereas in nearly all other continents invaded by these oceanic waters, there appear to be two well marked periods of diastrophic action. Then will be projected (4) another series of maps, indicating that the Ordovicic is not made up of a single submergence and emergence, as is commonly held, but that it in all probability embraces three cycles of diastrophic movement, of which only the youngest will be shown. Finally will appear (5) a geologic chart on which is drawn a curve showing in square miles the determined amount of the various inundations undergone by the North American continent since the beginning of the Cambric.

A. Siluric (Upper Silurian) Period.

The diastrophism in America is in general harmonious with that of Europe.

The writer has thirteen maps of which ten will be shown:—

General Emergence.

Eo-Siluric (Girardeau).
Eo-Siluric (Edgewood-Becsie).
Eo-Siluric (Brassfield-Cataract).

Movement of Appalachia.

Meso-Siluric (Medina).
Meso-Siluric (Clinton).
Meso-Siluric (Rochester).

Time of Greatest Submergence.

Meso-Siluric (Louisville or Upper Chicago).
Meso-Siluric (Guelph).

Retreat of Seas.

Neo-Siluric (Salina).
Neo-Siluric (Bertie, Eurypterus).

General Emergence.

B. Devonic Period.

The diastrophism in America is in general harmonious with that of Europe.

The writer has eleven maps of which eight will be shown:—

General Emergence.

Eo-Devonic (Keyser-Manlius) } Helderbergian
Eo-Devonic (New Scotland) }

Movement of Appalachia

Eo-Devonic (Ridgley) Oriskany.

Time of Greatest Submergence

Meso-Devonic (Upper Onondaga).
Meso-Devonic (Upper Hamilton).
Meso-Devonic (Genesee-Portage).

Retreat of Seas.

Neo-Devonic (Upper Chemung-Lime Creek)
Neo-Devonic (Bradfordian).

General Emergence.

C. Upper Carbonic (or Pennsylvanic)-Permic Period

The diastrophic action in America is not in harmony with that of Europe. The writer has five maps of which three will be shown to bring out the fact that in North America there is but one cycle of sedimentation whereas there are clearly two in Europe:—

Time of Greatest Submergence.

Middle Missourian.

Retreat of Seas.

Lowest Permic (Permo-Carboniferous).
Late Lower Permic (Capitan).

Appalachian Revolution and Close of Paleozoic Era

A very long land interval follows throughout eastern North America.

D. Cincinnatic Period

Equals Borkholm, Brachiopodenkalk and Leptænakalk of North Europe. The terminal part of the Lower Silurian or Ordovician of authors.

The writer has nine maps of Cincinnatic time of which six will be shown. The object of this presentation is to bring out the fact that the Ordovicic cycle of sedimentation in North America closes with the Trenton formation, while the younger, highly fossiliferous deposits so well shown about Cincinnati, Ohio, belong to another distinct diastrophic cycle, the Cincinnatic period. This movement seems to accompany the Taconic disturbance a period of mountain-making extending throughout the Appalachian mountains north of Virginia. To visualize this cycle we will begin with the

Time of Greatest Ordovicic Submergence.

Lowest Trenton (Prosser or first stage in Trenton).

Emergence of North America apparently not quite complete.

Eo-Cincinnatic (Utica).
Eo-Cincinnatic (Eden-Frankfort).
Eo-Cincinnatic (Lower Maysville-Pulaski).

Time of Greatest Submergence.

Meso-Cincinnatic (Arnheim).
Meso-Cincinnatic (Waynesville-Fernvale).

Retreat of Seas.

Latest Neo-Cincinnatic (Gamache).

General Emergence.

E. The New Geologic Time Table for North America.

On the basis of the paleogeography as now developed by the writer, and the diastrophism postulated by these maps, a curve (Plate I) has been drawn showing the amount in square miles of the various inundations throughout geologic time since the beginning of the Cambric. The North American continent, including all of Central America south to Panama, as at present emergent, has an area estimated to be about 8,300,000 square miles. This area is shown on the chart by the highest horizontal line or ordinate, and gives a ready basis for estimating the relative amount of inundation or emergence that the curve indicates for any given time. The other ordinates, numbered 3 to 8, are separated at intervals, each representing 1,000,000 square miles.

The vertical lines or abscissæ in the chart are eighty-eight in number and represent about the same number of paleogeographic maps so far developed by the writer. The time names of these maps appear in the lower part of the chart and are grouped in periods and eras according to the classification now in use. In all cases where the areal amount of inundation is not based on actual paleogeographic mapping or for other reasons is uncertain, this condition is indicated in the curve by a broken line. The time ratios given are those of DANA's estimate, though somewhat changed, giving twelve to the Paleozoic, six to the Mesozoic, and two to the Cenozoic. Attention is called to the great amount of time allotted to the Cambric and Ordovicic periods—together 43 per cent. of the Paleozoic era. The per cent. of time for each period is given throughout on the basis of the ratios mentioned, but it should be stated that these are rough estimates and not calculations based on the known thickness of the formations. Further, the chart makes no allowance whatever for the intrasystemic and intersystemic time breaks; those of longest duration are of course the hiatuses between the systems, and their effect, if properly drawn, would be to separate the periods by times of unequal and, as yet, unknown duration. On the other hand, the intrasystemic breaks, when fully understood, will probably modify the curve to a considerable extent, and bring out the oscillatory nature of the strand-line.

The new geologic time table based on diastrophism is given at the top of the chart, and can, therefore, be easily compared with the present one shown at the bottom of the table. The new arrangement follows the diastrophism plotted in the curve of the chart, and shows that there are seventeen cycles or periods recorded in the North American continent, provided the Tertiary actually includes two cycles. The old classification recognizes at best but thirteen periods.

A comparison of the curve chart here presented (Plate 1) with the one on Plate 11, published by the writer three years ago (1910, Pl. 101) shows the same general diastrophism. In other words, the further and more detailed plotting of the geologic data during the interval has not given results at variance with those of 1910, for the number of periods recorded on the North American continent is still found to be seventeen. It will be seen, however, that in detail there are many changes. These alterations are due to the breaking up of many of the synthetic maps into two or more paleogeographies of shorter time, resulting in far greater accentuation of the emergent portion of the period curves. Of these, the most marked change is in that of the Devonic, which curve new sharply distinguishes this period from the Mississippic, and thus harmonizes this diastrophic action with that of the other periods. In 1910, the writer concluded that the Devonic in the Cordilleran region "continued with but little physical change into the succeeding period," and that 20 per cent. of the continent seemed to have remained submerged during this interval and into the Mississippic (1910, p. 493). A further study of the late Devonic faunas and the breaking up into two maps of the synthetic map shown on Plate 77 (Ithaca-Chemung), with the additional reference of the Bradfordian to the Devonic instead of to the Mississippic has brought about this marked paleogeographic alteration.

A further study of the diastrophic curve chart of 1910 (Plate 11) shows the line illustrating the amount of the periodic submergences and emergences as quite regularly descending and ascending. On the other hand, the new chart (Plate 1) shows that the curve during at least the Ordovicic, Cincinnatic (slight), Siluric, and Tennesseic is oscillatory, a condition approaching the actual known records in the formations. As more detailed mapping is developed, the more oscillatory will become these submergent and emergent curves, and it will be this minor diastrophism that will group the local formations into epochs or series, and ages or stages.

We should now ask ourselves the question: Are these periodic crustal movements sufficiently clearly recorded in all or most of the continents to be in harmony with one another and thus establish in each a natural and identical systemic sequence? The answer can be made even now that in general the diastrophic record is harmonious throughout the world but that it varies more or less in detail in all of the continents. The most variant continent is Africa south of the Sahara desert, as it records no regularity in the pulsating overlaps such as is found in Europe, Asia and America. Throughout Paleozoic time the Indian ocean spread but once over a small portion of southeastern Africa, the record being the coarse Bokkeveld deposits of Middle Devonic time. The Mesozoic record along East Africa, is, however, much better, but on the west coast it is also absent. Present Africa is, therefore, a great remnant of a larger, continuously high-standing horst, of which undetermined areal quantities on the eastern and more especially the western sides have sunk into the Indian and Atlantic oceans.

The oceanic overlaps of Paleozoic North America are seemingly, in the main, in harmony with those of western Europe, but not wholly so. The most marked disagreement is seen in the Permic of Europe and Asia, where a complete diastrophic cycle is clearly recorded, while throughout the greater part of North America the marked Coal Measures overlap completely vanished shortly before the time when the Zechstein sea began its invasion over the former land masses. In America the Appalachian Revolution began its maximum of movement early in Permic time and the Atlantic ocean did not again overlap the continent along the eastern border until middle Cretacic time, and in the Gulf States not until Comanchic time. On the other side of the continent, however, the Pacific ocean regularly overlapped the west coast during Mesozoic time; and the maxima of the submergences, while not at all comparable in areal extent to those of Europe, appear to be in harmony with the pulsation of the strand-line as recorded in Asia and the Mediterranean countries.

The grand cycles or revolutions are easily recognized and appear to have affected the whole world at the same time, but the smaller periodic cycles, called epicycles by WILLIS, are seen to be more difficult to harmonize throughout the continents. WILLIS thinks these epicycles "are grouped according to several distinct dynamic regions [*i.e.*, the great oceans]. Each region has experienced an individual history of diastrophism in which the law of periodicity is expressed in cycles of movement and quiescence peculiar to the region. The cycles of one region have been, however, to some extent parallel, though not conterminous, with the cycles of other regions and thus major cycles of world-wide conditions are constituted by coincidence of regional conditions" (1910, pp. 247-248). This conclusion is undoubtedly partly correct, but that diastrophic action within the dynamic region of the Atlantic was dissimilar on its two bordering lands becomes plain as soon as we look into their structural detail. For instance, the Eopaleozoic is closed in America by the Taconic disturbance of late Ordovicic time, while in western Europe the natural division of the Paleozoic era lies in the Caledonian movement at the close of the Siluric period. On the other hand, the birth of the great Paleozoic Alps of Europe is not due to the Atlantic dynamic region, but is caused by the thrusts of the then greater Mediterranean (Tethys); and these movements are not harmonious either in time or direction with those of the Appalachian Revolution. It is probably these differences that develop a Permic diastrophic cycle in Europe and Asia, while at this time in America there is no invasion of the oceans.

The theory of dynamic regions with special records has valuable possibilities and should be made use of by paleogeographers. KARPINSKY in 1896, called attention to this matter in his valuable paper on the movements of the earth's crust in Russia. He states: "There took place in European Russia successive movements of the earth's crust consisting especially of sinkings, extending alternately in the direction of the meridians and the parallels. . . . The direction of the movements remained almost always parallel to the chains of the Caucasus and the Urals; during the most active period of formation of the Urals [*i.e.*, from Middle Carboniferous into Lower Cretacic time], the dominant direction of subsidence was along the meridians; during the formation of the Caucasus [from about Middle Jurassic time into the Cenozoic], subsidences parallel to this range took place . . . [and were] almost completely substituted for the meridional depressions" (1896, pp. 190-192).

In conclusion, we may truthfully state that there is a good deal of harmony among geologists and stratigraphers in their use of the theory that the surface of the earth is periodically and rhythmically in motion, and that this diastrophic action is at the basis of chronogenesis, developing not only cycles of sea invasion and land emergence but as well cycles of organic evolution. Although the eras are clearly recognizable everywhere, nevertheless, until the paleogeography of Europe is worked out in detail we shall not be able to say that the same periods in current use are established in nature. Until that time, it will be doubtless advisable for America to work out its own geologic chronology. At some later Congress, it is to be expected that an international committee will be appointed to establish a world chronology and a final taxonomy.

To make the information contained in the curve more easily comprehensible, the following table is appended giving in square miles and in percentages the areal amount of submergence and emergence that the North American continent has periodically undergone.

Postscript. At the meetings of the Twelfth International Geological Congress, held at Toronto, the writer first became aware of the scope of ULRICH's paper entitled, *The Ordovician-Silurian Boundary*. The main points of this paper are (1) that all previous stratigraphers, and especially SCHUCHERT, are in error in drawing the boundary between the accepted Siluric and Ordovicic at the top of the Richmondian series and beneath the Medina (the Upper Medina); (2) that all of the Richmondian is to be added to the Siluric, *i.e.*, the Siluric of ULRICH; and (3) that all of the Maysvillian and Edenian (including the Fulton and Utica) are to be referred to the Ordovicic as defined by ULRICH.

The object of the present writer's paper before the Congress was to call attention to the "cycles of earth movement." He also concluded that "the surface of the earth is periodically and rythmically in motion, and that this diastrophic action is at the basis of chronogenesis, developing not only cycles of sea invasion and land emergence, but as well cycles of organic evolution. Although the eras are clearly recognizable everywhere [not to ULRICH, as he refers all of the Coal Measures and Permic to the Mesozoic era, a reference in which he stands alone], nevertheless, until the paleogeography of Europe is worked out in detail we shall not be able to say that the various periods in current use are established in nature" (*supra*, p. 30).

The writer showed at the Congress, by a display of paleogeographic maps, that the Siluric [not of ULRICH] and the Devonic [not of ULRICH] are in most places satisfactorily delimited, and that the sea invasions in North America begin with small inundations (from 2 to 10 per cent. extent), rise to their climax (39 and 38 per cent. respectively), and finally recede to almost complete continental emergence (2 to 5 per cent.). He next demonstrated, according to the principle of diastrophism as illustrated by paleogeography, that the Upper Carbonic, or Pennsylvanic, and Permic periods are not separable in North America as they are in Europe and elsewhere; and finally, that the Ordovicic as usually accepted is really made up of three hydrosphere movements (according to ULRICH only two), only one of which, the Cincinnatic period (begins with 3 per cent. of inundation, rises to full flood at 41 per cent., and recedes finally to 1 per cent.), was illustrated by maps.

ULRICH objects to SCHUCHERT's boundaries of the Cincinnatic period and tries to show that the stratigraphic breaks between the Trenton and Utica, or Utica and Edenian, and again between the Richmondian and Upper Medina, are not of systemic value. On the other hand he states that "the Maysville-Richmond break has the diastrophic qualities to fit the requirements"; in other words, this break is of the desired period significance faunally and paleogeographically. He adds: "I propose to recognize the break between the Maysville and the Richmond, and between their correlates, as marking the boundary between the Ordovician and Silurian systems in America."

The writer is still a heretic in regard to these conclusions of ULRICH, even after several years' verbal discussion and a careful reading of the paper above cited. The subject of ULRICH's paper concerns not alone SCHUCHERT, but is in opposition to all American stratigraphers, and the great majority of text-books, consciously or otherwise, do not agree with ULRICH's faunal and diastrophic correlations as here set forth.

At the Congress, ULRICH also presented a series of paleogeographic maps showing the areal distribution of the various seas under discussion, and even though they differed somewhat from those of the writer, in no case were the areas illustrated as under inundation markedly different from those presented by SCHUCHERT. In other words, ULRICH's maps proved a diastrophic cycle almost identical with the Cincinnatic period as demonstrated by the writer. However, it should be added that ULRICH presented no maps of the earliest Richmondian seas, but even if he can show that these waters begin with a very small spread, it would still leave this inundation with the earmarks of a complete cycle of sea invasion and a marked diastrophic movement.

TABLE OF NORTH AMERICAN DIASTROPHIC CYCLES OF SUBMERGENCES AND EMERGENCES.

		Square miles submerged	Percentage submerged	Statement in 1910
	Cambrian of European authors.			
Waucobic	Lower Waucobic (Nevadia)	110,000	+1.	
	Middle Waucobic (Mesonacis)	870,000	+10.	
	Middle Waucobic (Olenellus)	1,550,000	18.	18%
	Upper Waucobic (Final Olenellus. Sea possibly continuous in Cordillera; complete land in Appalachia			
Acadic	Lower Acadic (Protolenus)	900,00	11.	
	Middle Acadic (Lower St. Croixan)	2,410,000	29.	31%
	Upper Acadic (Upper St. Croixan into complete land)			
Ozarkic	Lower Ozarkic (Briarfield-Ketona)	150,000	−2.	
	Middle Ozarkic (Potsdam-Copper Ridge)	1,915,000	23.	21%
	Upper Ozarkic (Shakopee-Roubidoux)	565,000	7.	
	Lower Silurian or Ordovician of European authors.			
Cambric	Lower Beekmantown (estimated)	800,000	+10.	23%
	Middle Beekmantown	1,800,000	20.	
	Upper Beekmantown (estimated)	500,000	+6.	
Ordovicic	Lower Ordovicic (St. Peter)	475,000	−6.	12%
	Middle Ordovicic (Stones River-Chazy. A synthetic map)	2,667,100	+32.	26%
	Black River (Lowville) about	3,000,000	36.	30%
	Black River (Watertown) about	2,500,000	30.	
	Black River (Decorah) about	2,500,000	30.	
	Black River (Kimmswick, estimated)	2,000,000	25.	
	Basal Trenton (Prosser or first stage in Trenton) about	3,900,000	47.	57%
	Middle Trenton (Wilmore or third stage in Trenton) about	633,250	−8	
	Upper Trenton (Catheys or seventh stage in Trenton)	283,000	+3.	
Cincinnatic	Lower Cincinnatic (Utica)	290,000	+3	10%
	Lower Cincinnatic (Eden and Frankfort)	350,000 to 475,000	4. to 6.	
	Lower Cincinnatic (Pulaski-Lower Maysvillian)	475,000	6.	
	Lower Cincinnatic (Maysvillian)	475,000 to 290,000	6. to 3.	
	Middle Cincinnatic (Arnheim)	390,000	−5.	
	Middle Cincinnatic (Waynesville-Fernvale)	3,365,000	−41.	40%
	Upper Cincinnatic (Gamache)	35,000	−1.	

TABLE OF NORTH AMERICAN DIASTROPHIC CYCLES OF SUBMERGENCES AND EMERGENCES—*Continued.*

		Square miles submerged	Percentage submerged	Statement in 1910
	Upper Silurian or Silurian of European authors.			
Siluric	Lower Alexandrian (Girardeau)	165,000	2.	
Siluric	Lower Alexandrian (Edgewood-Becsie)	250,000	3.	5%
Siluric	Upper Alexandrian (Brassfield-Cataract)	1,560,000	19.	5%
Siluric	Lower Niagaran (Medina)	410,000	5.	
Siluric	Lower Niagaran (Clinton)	775,000	+9.	14%
Siluric	Middle Niagaran (Rochester)	2,400,000	30.	34%
Siluric	Middle Niagaran (Upper Chicago)	3,200,000	39.	35%
Siluric	Upper Niagaran (Guelph)	2,875,000	34.	31%
Siluric	Lower Cayugan (Salina)	650,000	8.	6%
Siluric	Middle Cayugan (Bertie)	690,000	+8.	5%
Siluric	Upper Cayugan (Tonoloway)	420,000	5.	5%
	Devonian of European authors.			
Devonic	Helderbergian (Keyser-Manlius)	520,000	+6.	
Devonic	Helderbergian (New Scotland-Becraft)	850,000	10.	6%
Devonic	Oriskanian (Shriver)	850,000	10.	
Devonic	Oriskanian (Ridgley)	950,000	+11.	8%
Devonic	Middle Devonic (Upper Onondaga)	1,205,000	−15.	16%
Devonic	Middle Devonic (Upper Hamilton)	3,150,000	38.	35%
Devonic	Middle Devonic (Genesee-Portage)	2,840,000	34.	33%
Devonic	Upper Devonic (Upper Chemung)	1,310,000	16.	20%
Devonic	Upper Devonic (Bradfordian. Estimated)	200,000	+2.	24%
	Lower Carboniferous of European authors.			
Mississippic	Upper Chattanooga	960,000	12.	
Mississippic	Middle Kinderhookian	2,000,000	24.	
Mississippic	Late Kinderhookian (Fern Glen)	2,270,000	+26.	25%
Mississippic	Lower Osagian (Upper Burlington)	2,200,000	26.	20%
Mississippic	Upper Osagian (Keokuk)	1,650,000	20.	
Mississippic	Upper Osagian (Upper Keokuk. Estimated)	400,000	5.	5%
Tennessic	Lower Meramecian (Warsaw)	300,000	−4.	
Tennessic	Middle Meramecian (Spergen. Estimated)	600,000	+7.	
Tennessic	Middle Meramecian (St. Louis)	990,000	12.	7%
Tennessic	Upper Meramecian (Moorefield. Estimated)	500,000	6.	
Tennessic	Lower Ste. Genevieve	990,000	12.	13%
Tennessic	Upper Ste. Genevieve (Birdsville)	350,000	+4.	7%

TABLE OF NORTH AMERICAN DIASTROPHIC CYCLES OF SUBMERGENCES AND EMERGENCES—*Continued.*

		Square miles submerged	Percentage submerged	Statement in 1910
	Upper Carb, and Perm. of European authors.			
Pennsylvanic-Permic	Lower Pottsvillian	2,175,000	+26.	
	Upper Pottsvillian	2,585,000	+31.	27%
	Middle Missourian	2,290,000	+27.	18%
	Upper Missourian (Estimated)	1,950,000	24.	
	Lowest Permic (Permo-Carboniferous)	1,800,000	22.	
	Late Lower Permic (Capitan)	385,000	−5.	3%
	Middle Permic. North America emergent.			
	Upper Permic. North America emergent.			
	Triassic of European authors.			
Triassic	Lower Triassic (Meekoceras)	320,000	4.	2%
	Middle Triassic (Columbites-Tirolites)	415,000	5.	
	Upper Triassic* (Tropites-Halobia)	1,395,000	−17.	15%
	Upper Triassic (Close. Estimated)	300,000	−3.	
	Jurassic of European authors.			
Jurassic	Lower Jurassic (Hardgrave)	385,000	−5.	3%
	Middle Jurassic (Estimated)	500,000	6.	
	Early Upper Jurassic (Sundance)	1,550,000	18.	13%
	Late Upper Jurassic	715,000	+8.	
	Lower Cretaceous of European authors.			
Comanchic	Lower Trinity (Estimated)	500,000	6.	7%
	Upper Trinity	1,270,000	+15.	
	Fredericksburg	2,500,000	30.	19%
	Lower Washita	1,510,000	18.	
	Upper Washita (Estimated)	800,000	10.	
	Upper Cretaceous of European authors.			
Cretacic	Dakota (Bear River. Marine only, estimated)	860,000	10.	
	Lower Colorado (Benton)	2,590,000	31.	
	Upper Colorado (Niobrara)	2,780,000	33.	30%
	Lower Montana (Pierre)	2,390,000	29.	
	Laramie (Estimated)	400,000	5.	
	Lance (Entire continent probably emergent)			
	Cenozoic or Tertiary of European authors			
Eogenic	Eocene (Later Midway. Estimated)	500,000	6.	
	Eocene (Wilcoxan)	610,000	7.	
	Oligocene (Claiborne-Jackson)	295,000	+3.	3%
	Oligocene (Vicksburg)	335,000	4.	
Neogenic	Alum Bluff	350,000	4.	
	Lower Miocene	245,000	3.	3%
	Upper Miocene	365,000	+4.	4%
	Pliocene	80,000	1.	

*In addition to the marine extensions, there are in the Rocky mountains 420,000 square miles of fresh-water deposits.

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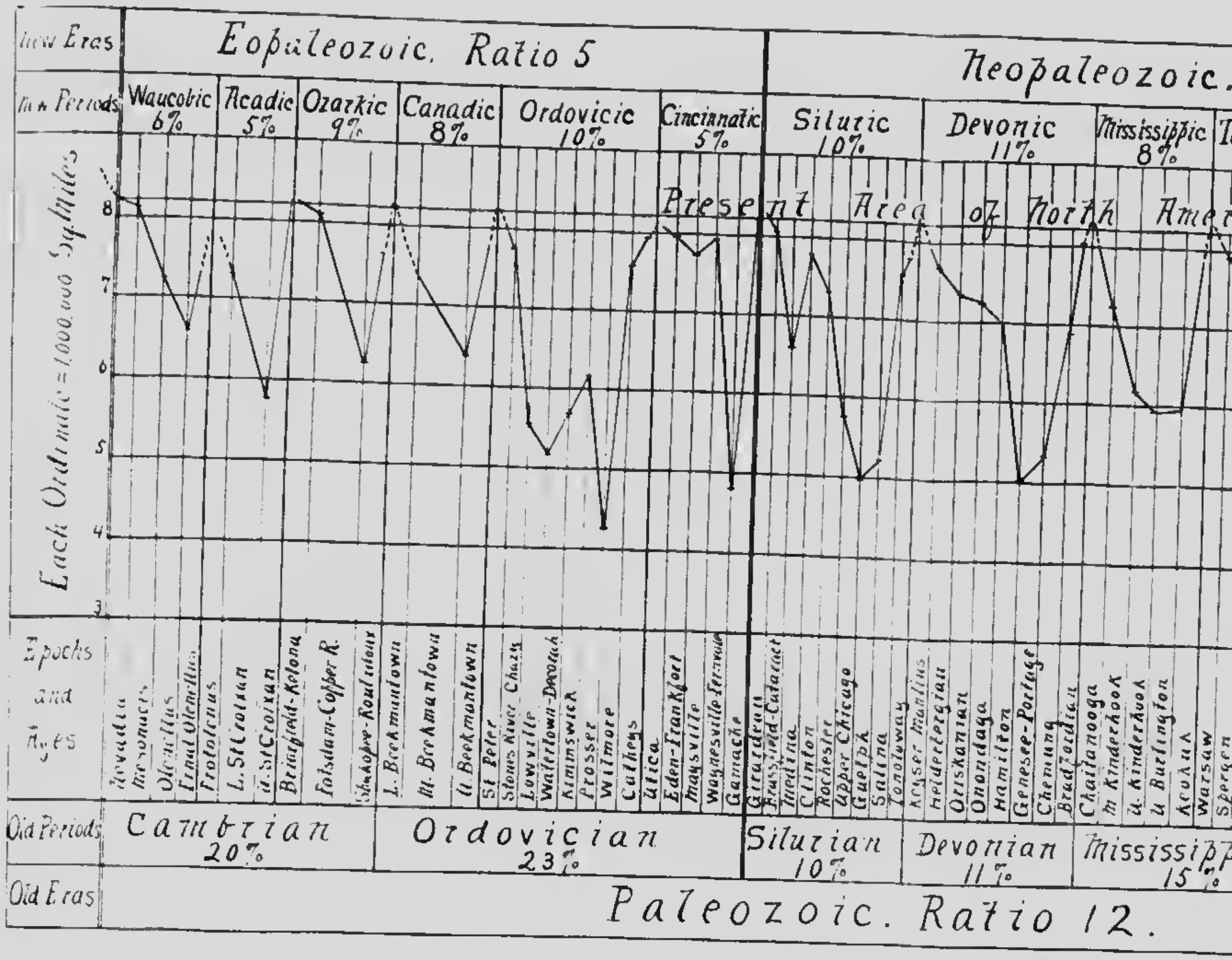

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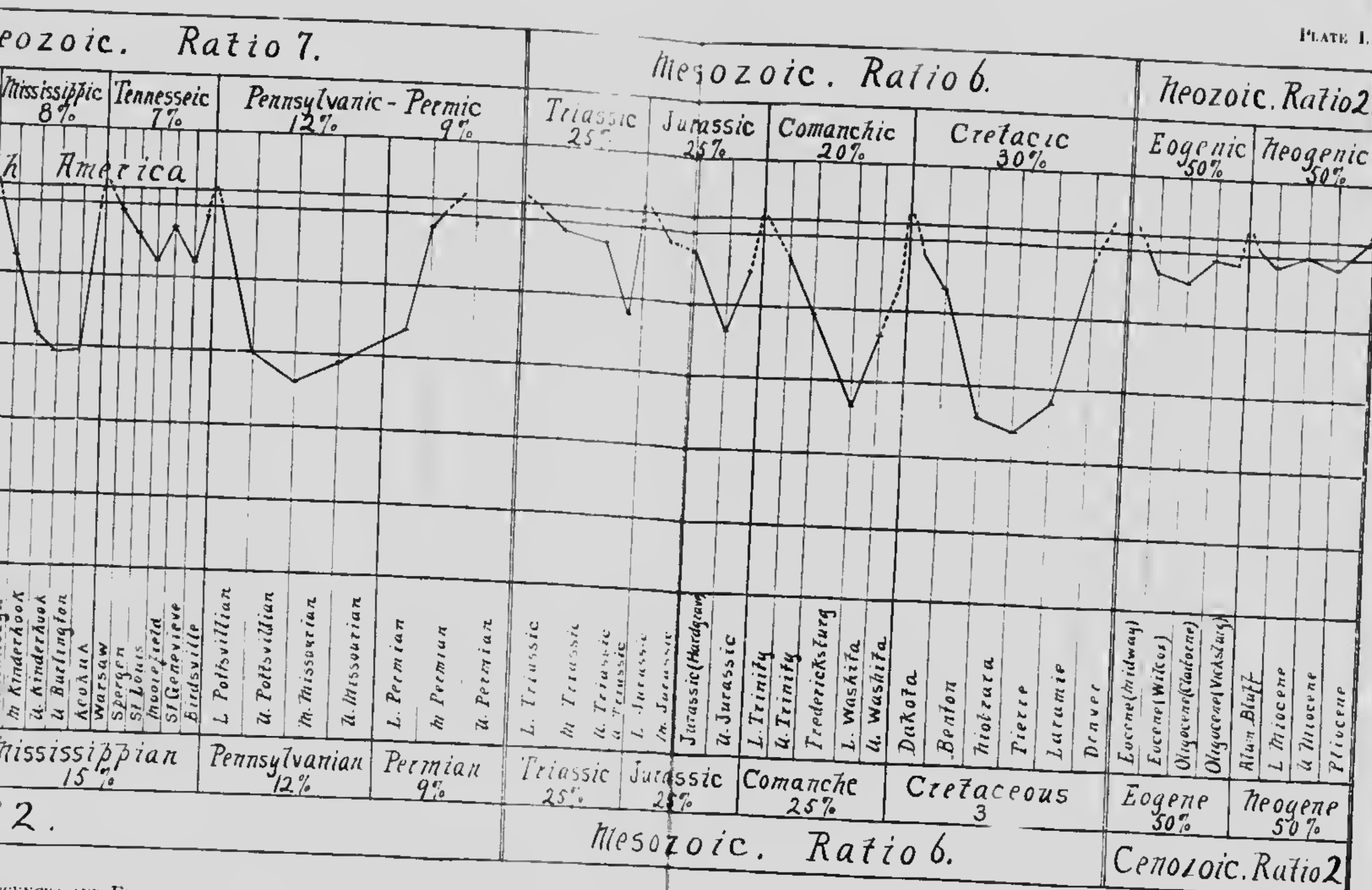
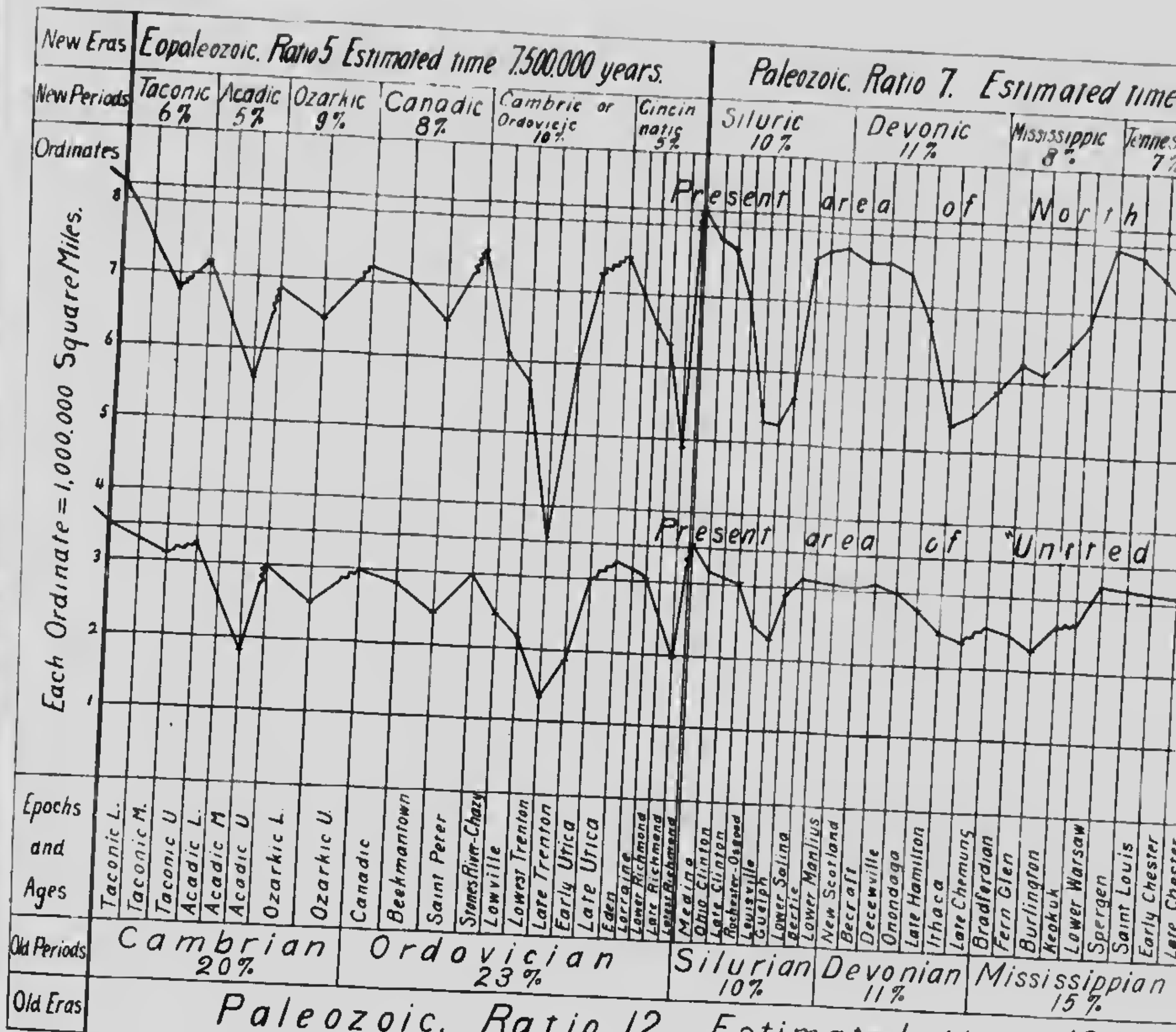
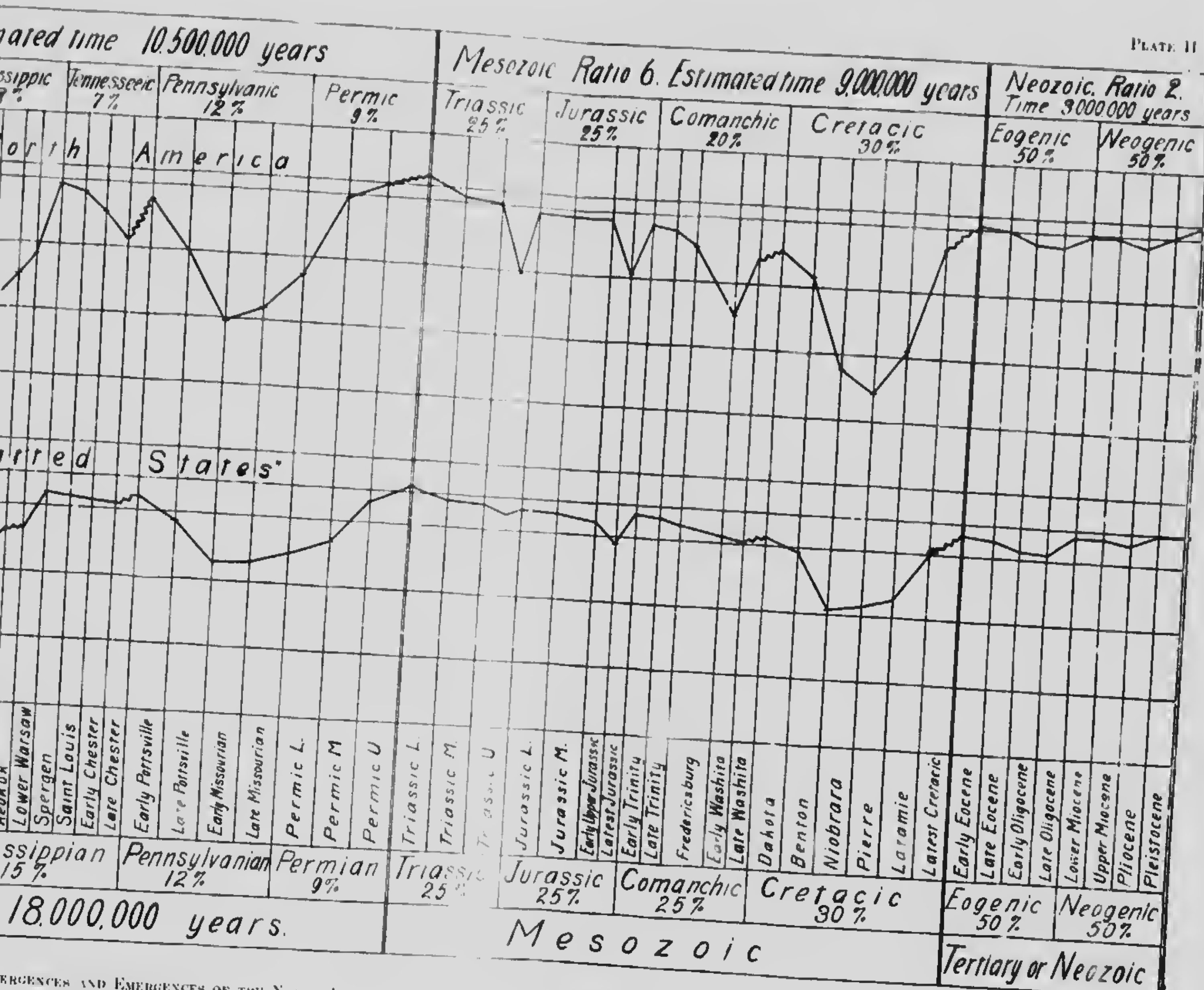


...GENCES AND EMERGENCES OF THE NORTH AMERICAN CONTINENT IN TIME AND SPACE.



Curve Prepared in 1910 Showing the Amount of Submergences and

PLATE II



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THE ORDOVICIAN-SILURIAN BOUNDARY.

BY

E. O. ULRICH,[1]

U.S. Geological Survey, Washington, D.C.

With eight maps and a table

The subject in whose discussion I have the honor and privilege to participate is an extremely broad one. It covers the science of stratigraphy; and this means that it covers also every branch of paleontology and that it touches most of those of structural geology and physiography. Being so comprehensive it is manifestly impossible to discuss even the general proposition in anything like an adequate manner in the short time allotted to us. Fortunately for me the Geological Society of America published less than two years ago a work entitled *Revision of the Paleozoic Systems*, in which I expressed myself rather fully on the geologic criteria and principles chiefly involved in this discussion. Since only the barest outline of the principles of stratigraphic correlation and taxonomy can be given here the reader is respectfully referred to the *Revision* for details. Before taking up this outline a few explanatory remarks seem desirable.

Unfortunately only a small part of the mass of data which formed the basis of the principles of correlation and taxonomy which are defined and illustrated in the *Revision* could be presented at that time. In fact most of the results of my stratigraphic investigations in the past twenty years have not yet been published. Immediate justification of my reluctance to publish the evidence as it came to hand is seen in those of my papers which, for one reason or another, it was thought necessary to issue during this time. Most, if not all of them, are sadly in need of repairs.

Some of the imperfections which are now so obvious in these papers are due to the necessity of adapting my conclusions to methods and opinions which happened to prevail at such times on the Federal Survey. The greater part of them, however, is to be ascribed to personal errors in observation and judgment, and to change in methods and views incident to the transition from the old to a newer conception of geological conditions. The bonds of convention and early training were too strong to be easily thrown aside.

In ordinary cases simple caution might well pass as a sufficient excuse for delay in presenting evidence. But this has not been an ordinary case. Great and really fundamental changes were contemplated. To insure the

[1] Published by permission of the Director of the U.S. Geological Survey as containing well considered opinions, some of which have not, however, been officially adopted by that organization.

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respect and confidence of my fellow workers in the science it was demanded that the innovations, which grew and grew with the progress of my investigations, must be supported by plausible and logical arguments and a wealth of irrefutable data.

To begin with I realized that many sections must be studied before the facts in any one of them can be properly interpreted. It became apparent also very soon that many sections must be studied again and again in the light of later discoveries. It is impossible to note every feature of a stratigraphic section on the first visit. This is particularly true when it comes to determining the relative weights of the several phenomena. Indeed, most important features may be at first entirely overlooked; and this may happen, as it has frequently to me, even when the facts are clearly displayed. But these repeated investigations required much time; and with so much to learn and such great opportunities as came to me in the course of my official work on the Federal Survey, there was no time for writing.

As I see it now it was really fortunate that I could not get time to write up the results of my investigations. I count it so because it is almost impossible to escape generalizations in describing sections. There were times when I would have determined one bed as Trenton, another as Utica, and a third as Niagara, and in each instance without sufficient data to insure the correctness of the correlation. In consequence these publications must have been burdened with immature and perhaps wholly incorrect conclusions that, consciously or otherwise, would have tended to bias subsequent determinations.

But the delay in publishing has not prevented the full and continuous use of the data—by others as well as by myself—so soon as they came to hand. We felt the great need of systematically correlated facts which might serve, at least temporarily, as a basis for practical criteria and principles of stratigraphic correlation. We aimed to attain more definite results than had been achieved theretofore; and with that end in view the original suggestions and theories were carefully tested in the field. If the tests proved satisfactory, then the ideas were accepted as good; if they did not apply truly, then we tried to learn why and wherein they failed so that they might be modified to fit the facts.

In these field experiments I enjoyed the efficient though generally critical aid and counsel of many of the geologists connected with the U.S. Geological Survey. Among these I am particularly indebted to C. W. HAYES, J. A. TAFF, G. W. STOSE, R. S. BASSLER, and CHARLES BUTTS. Other geologists also, notably J. M. CLARKE, H. P. CUSHING, and R. RUEDEMANN, of the New York State Survey, and CHARLES SCHUCHERT, of Yale University, aided very greatly in the trial and further development of the criteria and principles finally published in my *Revision of the Paleozoic Systems*. Without their support most of my efforts toward systematizing stratigraphic correlation and taxonomy must have proved weak and perhaps a complete failure.

These facts are brought out here not only in justice to the geologists mentioned, but to make it clear that between us a large amount of mostly unpublished information has accumulated. As much of it as can be will be incorporated in several large works which have been long planned and are now well on the way toward completion. Another reason for mentioning my associates in these investigations is to show the injustice of the accusation which has been made on several occasions, namely, that I see things that no other can observe. The fact is that I seldom work in the field alone. Consequently, nearly all of my field observations have been corroborated by or shared with competent stratigraphers. In many instances, too, it was necessary to establish the truth of my interpretations to the satisfaction of strong critics.

My final reason for the foregoing statements lies in the hope that they may be accepted as a sufficient protest against the criticisms of certain paleontologists who seem inclined to deny the propriety of using facts which have not previously been established in literature as part of the evidence on which general principles may be founded. Such criticism seems unjust because the existence of a fact is not dependent on its public demonstration It was no less a fact before its discovery; and it became an actual asset to whoever acquired it immediately following its acquisition. Moreover, once acquired, the new facts can not be ignored.

In framing the conclusions presented in my *Revision of Paleozoic Systems*, I tried to consider all the facts known to me, the unpublished no less than those universally accepted. Indeed, much of the new information proved of the greater value because it had been gathered with a definite and systematically directed purpose.

STATEMENT OF PRINCIPLES.

In my *Revision of the Paleozoic Systems* the criteria, principles, and methods of stratigraphic correlation and classification are carefully defined and discussed as fully as the space allotted to the work permitted. On the present occasion, however, I shall mention, with such comments as seem essential, only those principles which are regarded as pertinent to the present inquiry and also of primary importance in the conception and development of a truly systematic classification.

I. The first of these principles is concisely stated by the expression, "once a syncline always a syncline." In other words, areas that now exhibit anticlinal structure have always been characterized by relatively positive tendencies, while in those which are synclinal, negative tendencies predominated. The continents being a combination of positive and negative elements of which those of the former type prevailed over those of the latter, it follows that, from the beginning of the Cambrian, at least, on to the present time, the continental platforms have maintained essentially the same general form and location. Similarly, the oceanic basins, on the whole, have always been relatively depressed areas.

"Naturally, the distinctive characteristics of the positive and negative areas are developed to varying degrees, being strongly expressed in one case and perhaps but weakly in another. Besides, an area that is normally negative may be included in a broader area in which, taken as a whole, positive movements prevailed. Obviously the vertical movements of such an area must be purely relative, its attitude with respect to sea level being dominated by the emergent tendencies of the region of which it forms a part. Submergence of such an area of ill-recorded negative tendencies could occur only at times of unusual subsidence. On the other hand, relatively positive areas, as for instance submarine ridges and plateaus, may at times be dragged beneath sea level by the dominantly negative tendencies of the general area of which they form subordinate parts. It seems no more improbable, therefore, that intercontinental connections frequently rose out of the area of the present oceans, than that there are now and ever have been relatively low places or valleys on the emerged parts of the lithosphere.

"But aside from these modifications, which do not affect the idea seriously, the prevalence of positive movements in one region and of negative displacements in another has tended in corresponding degree to permanence in distribution of land and water over the face of the earth."[1]

The general truth of the principle of essential permanence of earth features is incontestibly established by the fact that in all anticlinal areas the marine formations tend to lap out, while their thicknesses here seem invariably to be inferior to those attained in adjacent synclinal areas. Moreover, those synclinoria in which the Cambrian formations are strongly developed usually contain also the greatest thicknesses of subsequent Paleozoic formations.

2. The second important principle pertains to the physical characteristics of Paleozoic lands and epicontinental seas. The Paleozoic lands, I take it, were in general much as they are to-day. Speaking only of the northern continents, the borders on the east, west and south were more or less elevated and subject to orogenic activities, while the great interior parts, including the northern margin, were practically flat and occasionally affected by gentle warpings of the surface. In detail, however, the present conditions, so far as relative relief and location of high lands are concerned, differ greatly from those which prevailed through most of the Paleozoic ages. The relief of the continents on the whole has increased with time. Further, the folded belt was located much nearer the edge of the continental platform than it is today. Finally, the interior plane is not only higher and more diverse in relief and dissection now than at any time during the Paleozoic eras but it shows in its structure the accumulated result of frequent warpings and of repeatedly alternating submergences and emergences.

As for the Paleozoic epicontinental seas, there is, so far as I am aware, no satisfactory evidence whatever indicating that any of them was very deep. On the contrary, and this is certainly true of North America, all of them seem to have been shallow and most of them probably did not exceed 200 or 300 feet in maximum depth. It appears further that none of these seas ever extended completely across a continent. It is true that such a condition is

[1] *Revision of the Paleozoic Systems*, p. 603

frequently indicated on paleogeographic maps of North America, but in every instance where these maps show Arctic and Pacific waters commingling with invasions from the Gulf of Mexico, I have satisfied myself that they are synthetic in that they combine two or more wholly distinct stages. As I see them, the Paleozoic epicontinental seas occupied mostly small, shallow, and often disconnected basins, communicating at one end or side with the nearest oceanic basin. In general they must have been much like Hudson bay, which, indeed, I regard as a modern representative of the American Paleozoic interior continental seas. These basins were filled and emptied many times, occasionally receiving their waters from the Atlantic, at other times from the Arctic, and ofttimes from the Gulf of Mexico. So long as the inland sea maintained a southern oceanic connection it varied in little except size. But with each change in the source of the waters the geographic pattern differed fundamentally from the next preceding.

In the Appalachian region the seas were often contained in narrow troughs which connected at some point with the Atlantic. Occasionally these troughs communicated at both ends with the oceanic basin whose margin they paralleled.

The lands being low and generally quite featureless and the seas shallow, it is inferred that the shores were gently sloping and, as a rule, broad mud flats or sand beaches. Under such conditions wave-cutting must have been almost negligible in amount. Surface erosion, too, must have been relatively insignificant, the chief factor in the process being subaerial decomposition. Obviously, under the inferred conditions, angular unconformities and coarse conglomerates could occur only in exceptional localities. As a rule, then, the physical evidence of even a long and otherwise unmistakably indicated period of emergence and consequent discontinuance of sedimentation in the interior areas of the continent is necessarily inconspicuous.

3. The third group of principles relates to the instability of the lithosphere and consequent displacements of the strandline. Using North America as a type, I showed in the *Revision* that the marine deposits of each of the many geologic ages varied more or less decidedly in distribution from those of preceding and succeeding ages. From this fact, and especially because the variations were differential in extent and direction and not regularly progressive or regressive, it was inferred that they were occasioned chiefly by more or less local or general deformative movements within the lithosphere. These movements were not confined to the marginal tracts of the continents, but affected in varying degree and manner all parts of the surface. In the median areas of the continents these deformations were relatively gentle and the vertical components of the movements were small, but on account of the low and featureless relief of the interior areas they caused great displacements of the strandline.

All diastrophic movements and processes have ever been characterized by periods of activity alternating with periods of relative quiescence. Periodicity, then, is a fundamental factor of geologic history. Further, all diastrophic processes must be rhythmic in operation and recurrence, because they are occasioned by the necessarily rhythmic action of terrestrial forces. Diastrophic movements, therefore, offer a systematic basis for classification.

Shifting of the strandline is a natural and inevitable consequence of surficially indicated body deformations of the earth. Disregarding certain qualifications, it is accepted as a fact that the effect of any vertical movement of the lithosphere is contemporaneously and universally recorded by some corresponding relative change in the level of the sea. These changes are usually indicated in the stratigraphic record by evidence of either advance or withdrawal of waters from the epicontinental basins, in other words, by some kind of stratigraphic or faunal break.

Within the same province of a given continent, and probably in those occupying approximately the same latitude in other continents, the change in the location of the strandline at a given time is likely to be of one kind, that is, the shore line throughout the concerned areas will either advance or retreat as the case may be. But when the rocks in distinct provinces are compared, especially when one is connected with the Gulf of Mexico or the Mediterranean and the other with the Arctic sea, it is commonly necessary to correlate evidence of sea withdrawal in the one with evidence of sea advance in the other. This necessity comes about through the proof that the northern invasions are but seldom, if ever, synchronous with those which came in from the south. Judging from abundant evidence it appears that, under conditions favouring Arctic invasions, the continents were tilted to the north so that emergence obtained in the southern parts. At other times it was tilted to the south, thus permitting southern invasions and causing emergence in the north. (See *Revision*, pp. 367 and 405.)

4. One of the cardinal principles of modern stratigraphy is that the *accessible depositional sequence*, at whatever locality and however obscure the breaks, *is always incomplete*. The more complete the stratigraphic record the more numerous the hiatuses; the fewer the breaks the greater their average time values; and the relative conspicuity of the physical signs of the break is never a safe indication of its importance. Two sandstones, or it may be two shales or two limestones,—one unit of each pair closely simulating the other—may be in such intimate contact that continuous deposition is suggested; and yet a great time break with emergence may often be proved to have occurred between the two parts of the apparent lithologic unit.

Neither is the relative volume of deposits nor their areal extent a safe criterion. Two or three periods may be locally represented in a few feet of sediments. This is really a common occurrence on the flanks of the Nashville dome, where the Silurian and Devonian are often represented by thin overlap wedges. On the flanks of the Ozark dome, indeed, not only the Silurian and Devonian but the Ordovician system as well is locally absent and never strongly represented. Here, then, three periods may be represented in a varying sequence of deposits aggregating but a few hundred feet in thickness. If these fragmentary records were all that was known of these systems, it would be very difficult if not impossible to prove their true significance in the time scale. Fortunately, each is represented elsewhere by thousands of feet of sediments. More fortunately still, we can prove by satisfactory evidence that the thin wedges represent only small parts—usually the upper part—of widely spreading formations of their respective periods, which happened to extend by overlap to accessible situations on these flanks from some other area in which a more complete record was laid down.

Of all the features of the new conception, the smallness of the continental seas and the frequency and rhythmic occurrence of the oscillations, which caused withdrawal and shifting of the seas from one basin to another and thus interrupted the process of sedimentation, will perhaps seem to the average geologist the most difficult to grasp. But these together constitute the very backbone of the revision. Without them the distant correlations largely fall to the ground or remain indefinite or unsystematized as they have always been.

It is not claimed that the basic ideas are new. It is merely proposed to apply them more generally than was heretofore contemplated. We have long recognized that some of the Paleozoic seas were small, that they occasionally shifted their boundaries and that there must be something akin to rhythm in the great deformative movements that were more or less clearly suggested in the stony record. But these phenomena were treated as exceptional and local and not as definitely connected with a general, systematically developed, diastrophic process. That the strandline moved in obedience to the gradual development of this process and registered its stages, and that it therefore offered a definite and easily applied basis for stratigraphic correlation and classification, was only partially acknowledged. CHAMBERLIN and SALISBURY recognized the importance of the factor in so far as the major divisions of the stratigraphic column are concerned, but the demonstration of its applicability to minor divisions no less than the major is the task now before us.

5. The principles of correlation by fossil faunas and floras are of the highest importance. But, like all other lines of evidence employed in age determinations and stratigraphic correlations, the apparent testimony of the organic remains requires to be carefully considered and checked before we are justified in accepting it as conclusive. Though the great value of fossils in stratigraphic correlation is universally and justly acknowledged, it is nevertheless a fact that, where very close and detailed age determinations are concerned, faunas have often led us astray. The fault usually lay much less with the fossils than with ourselves who presumed to interpret their testimony. Commonly our information was inadequate or imperfect either as to the exact stratigraphic relations of the specimens in a given collection or regarding the actual time value of certain species or faunas. The importance of the ever-to-be-feared latter possibility was again most forcibly impressed on me during the past month, when Mr. G. W. STOSE and I found an upper Cincinnatian (middle Maysville) bed in southwestern Virginia which contained, besides the usual diagnostic fossils, three species hitherto unrecorded from this zone. One of these is an orthoid that I have not yet succeeded in distinguishing from the common middle and upper Trenton

variety of *Hebertella borealis*. Heretofore, I placed great faith in the supposed extinction of this type of shell at the close of the Trenton. The second stranger is so much like the Medina and Clinton *Bucaniella trilobata* that I fear it can not be differentiated by well marked characters. As to the third, I would have identified it unreservedly as *Lingula oblonga*, a late Medina or early Clinton species in New York, if it had been found by itself. All three of the forms are extremely abundant.

Not infrequently we fell into error because our judgment was biased by preconceived ideas as to the age of the containing beds; and sometimes our standard conception of the fauna of a given time has been an unnatural composite of the life of two or more distinct time units. A good example of the last is found in the "Clinton fauna" of literature, the greater part of which is made up from the fauna of the *Rhinopora verrucosa* zone ("Ohio Clinton," Brassfield), while the remainder is derived from beds of the typical Clinton. That the stratigraphic and faunal distinctness of these two lithologically similar formations was not observed long ago is doubtless due to the fact that their geographic distribution is so different that they are seldom seen together in the same section, and when they are it is only their overlapping edges that are in contact. Ordinarily, therefore, they seem to occupy the same position in the stratigraphic sequence.

The criteria and principles of paleontologic correlation are fully discussed in the *Revision*, pages 281-680. The principles therein presented were logically determined by field experience in the application of fossil evidence in stratigraphic correlation. The practical utility of the principles lies chiefly in seeking to take fully into account the many pitfalls that lie in the path of the paleontological stratigrapher. Greatest among these dangers are those which arise from recurrences of species and faunas, from provincial differences due to peculiarities which distinguish the development of life in the several oceanic basins, and from the effect of currents on the distribution of certain faunal elements.

When Edward Forbes and other students of marine zoology showed the great local variation in the character and number of organisms which exists along the present coast-line of Great Britain, paleontologists seized upon the idea as a satisfactory explanation of the local faunal differences observed in supposedly contemporaneous beds. Generally these correlated beds differed in lithologic character, one perhaps being a limestone, the other a shale or may be a sandstone. Occasionally the sandstone contained no fossils at all; or when organic remains were present they differed more or less decidedly in kind and abundance from those observed in the limestone and shale deposits which were believed to have been laid down in other parts of the marine basin at the same time as the sandstone. In other words the faunal differences were ascribed to differences in environment, such as varying littoral and bottom conditions which, while favouring the development of most kinds of marine life in some cases, or only certain kinds in others, were distinctly unfavourable to all in the remaining instances. That such varying conditions obtain to-day is too firmly established to be questioned.

Nor can we doubt that similar variation in distribution affected also the faunas of past geological ages.

Though admitting the general validity of the proposition there yet seem to be good reasons for questioning the wisdom of its acceptance as a vital and generally applicable factor in practical stratigraphy. There are so many contingencies that may seriously affect, if they do not entirely vitiate, the conclusions so readily drawn from the indiscriminate application in geology of the perfectly true idea that the composition of a marine fauna, nay, its very existence, is largely influenced by or dependent on environmental conditions. That the practical value of the principle in stratigraphic paleontology is commonly overrated should be clearly seen by those who will undertake an extensive comparison of the matrix in any large collection of fossils. He will find that the character of the rocks in which the fossils are found has no definite relation to the kinds of organic remains contained in it. Whether the rock is a limestone, a shale, or a sandstone, providing only that it is a marine deposit, there is no material difference in the kinds of fossils found in each. Not only the same classes and genera, but often the same species are equally abundant in all three kinds of rock. This, at least, is the testimony afforded by my own experience in the field study of Paleozoic fossiliferous rocks; and the results of comparative studies tending to show the relations of Cambrian genera of Brachiopoda to particular kinds of sediment, recently published by WALCOTT,[1] seem to be quite in accord with my own conclusions.

It is a well-known fact that the composition of the fauna at particular points of a coast may vary considerably from time to time. Indeed, certain limited stretches that only a few years or decades ago teemed with life are now barren. In other instances the opposite reversal has occurred. But such minor and probably irregular lateral shifting of faunas could not be positively recognizable in the fossil state. In the course of the time required to lay down a single layer of limestone, say a foot thick, these small lateral changes in faunal habitat very likely occurred many times. Unproductive seams in the layer may often suggest the barren intervals, but as a rule, and this should be more particularly the case in the slowly deposited limestones, the fossiliferous layer gives no clear indication of their occurrence. Besides, even if the fauna was occasionally withdrawn locally, the record of the fact would be obscured and apparently negatived by the transporting effect of waves and currents on dead shells and other organic remains derived from neighboring colonies. Thus, between the usual slowness of deposition, the normal to-and-fro shifting of habitat, and the more or less fortuitous transportation of dead shells the stony record is only exceptionally a true representation of the actual facts pertaining to faunal distribution at any particular time. The record for those parts of the fossilized bottom which may have been commonly barren stretches of the ancient sea coasts is therefore necessarily a more or less composite picture in which the hard remains of the life in adjacent areas are mingled with the remains of organisms that

[1] WALCOTT, C. D.: U.S. Geol. Survey Mon. LI, p. 150, 1912.

occasionally lived in these places. Reasonably exact records of the fossilizable life of any given spot of the littoral zone were possible only when the colony was suddenly buried beneath sediment that was not subsequently disturbed. This occurred commonly enough in the case of sandstones and shales, which for the same reason have given us our most perfectly preserved fossils, but took place only very rarely where calcareous and magnesian deposits were being laid down. Perhaps the best exceptions to the rule in the last cases are to be found among the limy reefs. When these are fossiliferous, like those in the Irondequoit limestone of New York or certain parts of the Mesodevonian of Michigan, the fossils found in the depressions of the reef probably represent very fairly the fauna that actually lived in or on the reef.

Paleontologists persist in forgetting that geological time is very long. Most of us, too, fail to bear in mind that species and faunas, given an unimpeded way, migrate from place to place so rapidly that we can not hope to measure the progress of the transgression stratigraphically. Adequately considered, these two facts will not permit us to assume without abundant corroborative evidence that the absence at one place of a fauna that is commonly present in the formation with which we may be inclined to correlate the unfossiliferous rock, is explainable on the ground of original difference in habitat. Neither are we justified in applying this possible explanation in accounting for radical differences in the faunas of beds that are unlike in lithologic characters, but occupy seemingly equivalent positions in the stratigraphic scale. In both instances experience teaches that the concerned beds are most probably not contemporaneous; and when the differences in the two faunas are great, it is more likely to prove that they owe their distinctness to derivation from distinct oceanic realms.

Abundant evidence has accumulated tending to show that two or more faunal aggregates may contain in common a large percentage of identical or closely allied species and yet differ widely in age. Simulating faunas like these usually signify recurrent invasions from the same oceanic basin. They indicate also the extreme slowness of specific mutation, and further, that the modification of a fauna of a given realm is to be ascribed to incorporation of migrants from other centres of dispersal and to local or partial extinction of the indigenous species rather than to evolutional modification of the latter. Finally, they indicate that very decided faunal breaks between contiguous formations whose respective ages are not so greatly different have resulted from the alternate capture of a given continental basin by waters invading from distinct oceanic basins.

Complete changes in the source and direction of the faunal invasions seem to have occurred frequently in the Appalachian troughs. Here Atlantic invasions are repeatedly superseded by incursions from the Gulf of Mexico, and occasionally one seems to have come in from the north. From the standpoint of correlation by fossil contents it is a significant fact that the recurrent Atlantic invasions always resemble each other more closely than they simulate the southern or northern invasions with which they alternate

The principle is well illustrated by comparing certain superposed Medina and Clinton faunas in western New York. Thus, while the general composition of the late upper Medina *Rhinopora verrucosa* fauna is strikingly like that of the late Clinton-Rochester shale fauna, both of which invaded from the Gulf of Mexico, neither is at all like the intervening faunas of the lower and middle Clinton divisions which invaded from the Atlantic side. The Rochester is followed in New York and Ontario by the totally different Guelph-Lockport fauna—a northern invasion. Evidently, a long interval of non-deposition separates these two formations in New York. In Indiana, Tennessee and other places in the southwest this interval is broken up into smaller gaps by intervening invasions from the south. In one of these—the Waldron shale—we recognize another, though, as a rule, specifically modified recurrence of the Rochester fauna.

If the fact of recurrence in these instances of closely simulating faunas were not apprehended, mere "matching" of species would most likely lead to erroneous correlations. But we have learned that in all such cases the recurrent fauna is accompanied by certain new things which are strictly diagnostic of each invasion. Instead, then, of relying on the general aspect of a fauna in making a close age determination, we select and depend more and more on such of the new species, and particularly on certain definitely traceable and limited invasions of one or more species—new or recurrent—which have stood the test of time and abundant trials and thus earned our confidence. But, after all, the value of our criteria is determined by experience. Possible exceptions should ever be held in mind; and whatever rules we make they must never be applied unreservedly except in the areas in which they have been proved. However excellent a guide a given fossil may be in one trough, or basin, or province, its correlation value in another area may be very small or altogether different. *Amphithecа hemispherica*, *Atrypa marginalis*, *Atrypa reticularis*, and *Pentamerus oblongus* are good examples of such locally varying values. The first is confined to the Clinton group in the Appalachian valley and is to be found in nearly every fossiliferous bed of the group. In the Anticosti section, however, its range includes beds corresponding in age to the upper Medina. Essentially the same is true of *Atrypa reticularis* which is absent in the Appalachian Medina, but is commonly present in the Clinton of this province. *Atrypa marginalis* has a wide range in Anticosti but seems to be confined to a much narrower zone in the Appalachian and Mississippi valleys. *Pentamerus oblongus*, so far as known, is confined to a thin zone in the southern Clinton and to two thin limestones in the Clinton of western New York. In Anticosti it lived earlier, but its main occurrence in Ohio[1] and Iowa is later than Clinton. The true significance and proper application of fossil evidence in stratigraphic

[1] This statement refers to the occurrence of the species in the Springfield limestone. According to FOERSTE *Pentamerus oblongus* is very rarely found also in the Dayton limestone, which overlies the "Ohio Clinton" or Brassfield zone and is regarded as early to middle Clinton in age.

correlation are discussed with special reference to the determination of the Ordovician-Silurian boundary on pages 626-632.

6. *General comments on methods of classifying sedimentary rocks.* In my opinion each of the taxonomic schemes that marked former stages of our science contains some features that makes it an improvement on its predecessors; and, doubtless, others will be presented after this that will be similarly distinguished. Therefore, no claim to permanency can be made for the best we can offer now. Indeed, it is doubtful if an altogether satisfactory arrangement is possible. Geologic history is too complicated to lend itself readily to systematic classification under prevailing conditions. The main difficulty lies in the discoördinateness of the units of the several grades, especially the "formations"; and purely personal factors add continually to our embarrassment. One goes in for extreme detail and he names every bed that can be distinguished by peculiarities in character of rock and fauna. Another is not so conscientious; and he may give a new formation name to a mass that would be better referred to under the name of the group, series, or system which it represents. Yet the nomenclatural product of both is governed by the same rules. Often the systematic stratigrapher might help himself easily enough except for some rule of nomenclature which forbids his desire to modify the original definition of the incongruous unit. Rigid rules have their bad as well as good qualities. Fortunately, our rules permit us some latitude in the redefinition and application of group, series, and systemic terms, though even in these cases we are bound rather more than is desirable by precedent and the exact form of the original definition.

But the most prolific source of disagreement and ensuing embarrassment lies in the prevailing disregard of uniformity in taxonomic methods. One geologist bases his judgment regarding the position of a given bed in the time scale solely on the general aspect of the fauna of the bed in question; another considers the introduction of new faunal types, or the mere presence of one or more supposedly characteristic species, as surer, or at least more definite indications of a particular time; a third considers both of these methods but is finally guided chiefly by physical criteria indicating displacement of the strandline and changed relations of land and water areas. The first and second depend either wholly or chiefly on strictly faunal criteria, the third follows the more comprehensive diastrophic method. Because of these differences in method, stratigraphic taxonomy is burdened with striking incongruities of unit grouping. In one case the two adjoining systems, as, for instance, the Devonian and Mississippian, were originally divided solely according to paleontologic criteria, in another the diastrophic criteria of unconformity and change in character of deposits were the predominant factors that determined the location of the dividing line. Somewhat different, though no less illustrative of the thought, are those cases in which the deposition of clastic material adjacent to an obvious break in geologic history has been interpreted as the closing episode of the preceding period or epoch while similar occurrences in other parts of the scale have been described as the introductory stage of the succeeding time.

Perhaps even more common and troublesome are those inconsistencies which have resulted from the application of the diastrophic method in one area and the purely paleontologic in another. An instance of this is found in the Ordovician-Silurian boundary which was drawn in New York, and in the Appalachian region generally according to the former method. In Ohio and adjoining states to the west and south, however, certain highly fossiliferous beds that are now known to correspond to deposits in New York that have always been classified as Silurian, were placed in the Ordovician column because the fossils looked that way. In New York the Ordovician fauna ceases abruptly with the Pulaski; and this is succeeded by thick masses of sandstone and shale in which organic remains are unknown. But in Ohio the equivalent of the Pulaski is followed by the fossiliferous McMillan, and this by another group of beds—the Richmond—which passes laterally into the lower Medina (or Queenston) of New York. So long as our knowledge of the life of the Medina was confined to the few things published in the New York reports, the rather strongly Ordovician aspect of the Richmond fauna completely masked its true age relations. Although the Richmond fauna now looks less like the Cincinnatian than it seemed to formerly, while the resemblance to the upper Medina fauna is much clearer than it was, the case nevertheless shows how greatly our conclusions may vary under different methods of determination. Similar incongruities in the classification of the Paleozoic rocks of Great Britain are indicated by generalized lists of fossils published in recent textbooks. Doubtless these are ascribable, at least in part, to similar miscorrelations of faunal and diastrophic criteria.

Considering the varying methods that have operated more or less independently in building up the present classification of sedimentary rocks, incongruous results are to be expected. In discussing these results decided disagreements are unavoidable, for, if we do not agree in methods our conclusions must necessarily differ in corresponding degree. And yet the arguments on the various sides may be entirely logical and though leading to very different conclusions, none can be justly accused of error in judgment. Each may be right from his viewpoint; and each may have excellent precedents for his mode of reasoning. But this does not help us to a systematic classification of geological formations. That desirable end is possible only under agreement; and the agreement must be on the matter of *method*. More than that, we must insist on *consistency* in the application of the chosen methods. This consistency in method, without which a really scientific classification of the sedimentary rocks, and thus of the geologic ages which they represent, is impossible, should pertain (1) to the criteria which shall determine where stratigraphic boundaries of whatever grade should be drawn, and (2) to those which shall determine which combination of units is to be ranked as a group, which as a series, and which as a system. In my opinion diastrophism affords the only means of finally attaining a reasonably accurate and systematically constructed classification.

For the reason that many of our "formations" are based on purely lithologic distinctions, some may rightly claim no greater importance in

stratigraphic taxonomy than is accorded to "members." Others, on the contrary, may include beds representing two or more elsewhere readily distinguished formations. In general practice, therefore, the latter are "groups," but they may be either greatly inferior or much superior in time value to a technical group. Until we have acquired adequate information regarding the value of each of the several components of such a group, more or less uncertainty and inconsistency in the classification of these primary combinations of stratigraphic units is unavoidable. But this weakness of a growing science can not excuse the neglect of systematic practice in those cases wherein our information is adequate.

Preferred methods and principles of stratigraphic taxonomy[1]— .. the study of stratigraphy the first essential is some comprehensive and systematic method of classifying geologic events. It has long been agreed that the only satisfactory basis for such a classification is the chronologic. The prevailing scheme recognizes, in ascending order of rank, *ages*, *stages*, *epochs*, *periods* and *eras*. The merits of the scheme, so far as its form and mode of arranging the several grades of units is concerned, have been proved beyond question. It is systematic, convenient, and practical, and so long as the quality of convenience is retained among the essential attributes of a classification, it is also as natural as it can be made. Changes recently introduced, and which I believe to be demanded by advance in knowledge, affect the scheme chiefly in the way of its more systematic application. Co-ordination of the units, which it seems to me is the basic principle of a systematically constructed scheme of classification, necessitated a general reorganization. This resulted in demotion in some instances and promotion in other cases of units that had hitherto been accorded ranks either superior or inferior to what a careful study of the facts seems to warrant.

The next step is the selection of some principle that shall guide us in determining when a geologic age has ended and a newer age has begun. Obviously, such a principle should apply similarly to all the divisions of the geologic time scale, the larger divisions up to periods and eras being but combinations of the minor units. Concisely stated, the beginning or end, as the case may be, of a terminal unit of a stage, epoch, period, or era at the same time delimits the division of higher rank of which it forms a part.

Lithologic criteria and the vertical range of fossils have hitherto been employed in seeking to fix these boundaries. For many reasons the results have been deplorably indefinite and often quite inaccurate. The need of some more exactly determinative and finally dominant criterion is undeniable. We require something that will supply the deficiencies of the purely paleontologic and lithologic methods and thus insure greater accuracy in stratigraphic correlation, in short a supplementary criterion by means of which the deposits of one age may be sharply distinguished from those of the next preceding and succeeding ages. The means is at hand. It lies among the criteria of diastrophism, namely, the alternate advance and retreat—displacement—of the strandline.

[1] See *Revision of the Paleozoic Systems*, pp. 574-607.

As defined by me the criteria of diastrophism embrace all physical and, to a certain extent, all organic phenomena implying horizontal and vertical movements of the crust of the lithosphere; also surface deformation which may aid in the causation of such body movements. Diastrophic processes, therefore, range from the impulsive grand deformations—which may be more local than general in their manifestation—to those much more gentle but stratigraphically important and often widely manifested movements which originate through the operation of degradational processes, and serve to maintain the isostatic equilibrium of the shell. Whatever the cause of these body deformations and, however manifested, they always tend in some larger or smaller degree to cause displacement of the strandline. If the movement resulted in a deepening of one of the oceanic basins, increasing its capacity, the waters must correspondingly be universally and simultaneously withdrawn from the epicontinental basins. If, on the contrary, the capacity of the oceanic basins is diminished by sedimentation, the waters must gradually overflow the land. As in the first case, so in this, the effect on the strandline is universal and similar on all the continents. But there were many deformative movements—they include, indeed, most of those which affected the continental parts of the lithosphere—in which the effect on the strandline could not have been similar either as regards the several continents or different parts of the same continent. If the surface of a continent was warped or tilted in any way, the displacement of the strandline necessarily differed in direction on different parts of the continent; and on the other continents at such times either advance or retreat of the coast-line may have occurred. Though exact correlation of these variously manifested and relatively local differential movements of and within one or another of the "positive" parts of the lithosphere is often exceedingly difficult, the fact yet remains that all of them occasioned some displacement of the strandline; and with this clue the difficulties are never insuperable.

Having adopted the periodic "displacement of the strandline" as the dominant criterion in determining the natural divisions of geologic history, we are ready to formulate the guiding principle. A geologic age is regarded as having closed when the marine waters are largely or wholly withdrawn from one or more of the epicontinental basins, the succeeding new age as having opened when the sea again began to advance in the same or in other basins. In the practical application of the principle the local stratigraphic sequence is divided at the first plane beneath the introduction of a new or recurring fauna, or beneath any well-marked faunal change, that exhibits evidence of diastrophic movements and consequent displacement of the strandline. Commonly the bounding plane is merely uneven, but in many instances the bedding planes on either side of it are more or less distinctly discordant. Such boundaries always indicate a stratigraphic hiatus or "unconformity." The time value of the hiatus is usually indicated, though as a rule not completely, by sediments laid down and preserved in other areas.

The succeeding steps pertain to the grouping of the minor units, in other words to the determination of what shall constitute a geologic period or system, and what an epoch or series, or a stage or group. The minor divisions of the time scale, that is the geologic "ages," being distinguished from preceding and succeeding ages by the reversal of the movement of the strandline, it seems desirable, on the ground of consistency, that the same principle should govern in deciding the limits of the larger time divisions. In practice then, we should endeavor to draw the boundaries between stages, epochs, and periods uniformly at horizons marking the greatest and most widely recognizable stratigraphic breaks or hiatuses, and the greatest shifting and change in pattern of seas known to have occurred during each of the eras, periods, or epochs. In the case of eras the boundary should be drawn at the most widely recognizable horizon of this kind found at or near the base of beds whose composition and structure indicate activity of diastrophic processes of the highest grade. In the case of periods or systems the boundary should be drawn with due regard to the matter of rhythm in the progress of geological history; and it should always be at some definitely recognizable stratigraphic break. This in turn should mark a considerable change in the average expression of paleogeographic patterns, particularly in the provincial boundaries, that had prevailed during the greater part of the preceding period. Great changes in provincial boundaries necessarily indicate important surface warping that extended to areas not at all or but slightly involved in the deformative movements of the preceding period.

If diastrophic movements of this kind and grade can be shown to have occurred more than once within the time included under the original or prevailing definition of any period, especially if the volume and time value of the deposits referred to such a complex period have become excessive in comparison with other periods, it seems to me desirable to restrict such a period and to introduce whatever new divisions that may be required to adequately express the facts. Indeed, this course seems obligatory if consistency of method and co-ordination of units are to be included among the desirable features of our classification. In my opinion these two qualities are indispensable features of systematic taxonomy. Following my convictions in this matter I have recently divided the Eopaleozoic era into four periods or systems instead of the two—Cambrian and Ordovician—hitherto recognized. Though the new systems are given intermediate positions between the Cambrian and the Ordovician, it should not be supposed that they are constituted wholly by restrictive definition of the older terms. On the contrary, the greater part of each is made up of thick formations whose position in the standard geologic scale had been misinterpreted. While it is true that the "Saratogan series" of New York has been removed from the Cambrian to the new Ozarkian period, it is also true that these transferred beds are younger than most of their previously supposed equivalents in the Appalachian and Mississippi valleys and elsewhere in America. Accepting the Wisconsin section as a typical development of the American Upper Cambrian, it follows from what has been said that our previous conception of the Cambrian system is not materially affected by the introduction of the new Ozarkian system; and, if we except the transferal of miscorrelated formations, the definition of the American Cambrian[1] remains essentially as heretofore.

Regarding the third Eopaleozoic system, for which DANA's term Canadian has been adopted, it must be admitted that it is made up almost entirely of formations heretofore classed as early Ordovician. In this case therefore the recognition of the new system necessitates a notable restriction of the prevailing definition of the Ordovician. The proposed restriction is justified on the ground that the Ordovician as originally defined, or rather as represented in America, is divisible into two approximately co-ordinate but otherwise quite distinct parts, each of which is comparable in thickness of deposits, time value, and diastrophic history to either the Silurian or the Devonian system. LAPWORTH's original definition of the Ordovician system being so greatly modified in this new arrangement, it may be objected by some that the old name is not properly applicable to either of the two parts. That course, however, would finally result in the complete obsolescence of LAPWORTH's term. Rather than this I much prefer restriction. Little confusion seems likely to arise from the change since the name is retained for the part containing the formations which are by far the most typical of the old system, namely, the Bala and Caradoc in Britain, and the Chazyan and Mohawkian series in America.

Before closing this summarized discussion of methods and principles I wish to mention a matter concerning which much looseness of practice prevails and which really is of much greater importance than is commonly thought. I refer, namely, to certain of those deposits which are usually described as "transition" or "passage" beds. To begin with, it is to be remembered that the basis of stratigraphic taxonomy is primarily chronologic; also that the beginning of the new age is marked in every case by the first depositional evidence of the return of marine waters.

Calling these usually clastic deposits transition beds serves in most instances to mask their true character and significance. This is so particularly when the underlying formation consists largely or wholly of such detrital matter as sandstone or shale. Emergence of such a formation and consequent subjection of its surface to subaerial agencies of erosion and decay, followed by resubmergence would as a rule cause reworking of the loosened surface material and produce an intermediate deposit that must necessarily partake in some degree of the character of the underlying formation from which a greater or smaller proportion of the material was derived. If the succeeding deposit is of finer detrital material than that composing the underlying formation, or if the newer deposit should happen to be a limestone, the intermediate bed may well suggest "transition;" and the character of the "passage" bed, as compared with the preceding and succeeding deposits,

[1] I say American Cambrian so that I may not be understood as referring also to the Cambrian as defined by European geologists. In Great Britain, for instance, the Cambrian includes deposits that seem to correspond to beds referred in America to the lower part of the Canadian system.

would be essentially the same whether the interruption of the process of deposition at the locality in question was of relatively brief duration or persisted through several geologic periods. But the point chiefly aimed at is that however greatly these deposits may simulate the underlying beds, for which reason the two are commonly referred to the same formation, the former really marks the beginning of, and belongs to, the age of the overlying formation. The true boundary between the deposits of such often widely distinct ages, therefore, is to be looked for beneath the deceptive "initial" deposit, and not above it.

THE "CINCINNATIC" SYSTEM OF SCHUCHERT.

In his recent work, *Paleogeography of North America*,[1] SCHUCHERT proposes a new system for which the term Cincinnatic system or period is adopted. His definition is preceded by the direction, "see Ulrich's paper for the detailed discussion of this system." Evidently Prof. SCHUCHERT misapprehended my views on this proposed system, for I did not then, and do not now, favour its recognition. As the "Cincinnatic" offers another way of solving the problem of the Ordovician-Silurian boundary in America a statement of the reasons which have led me to reject Prof. SCHUCHERT's proposal seems desirable here.

As defined by SCHUCHERT the Cincinnatic begins with the Economy zone of the Eden group of shales and closes with the last or Elkhorn zone of the Richmond group. Between these two groups is the Maysville group. The type area lies in southwestern Ohio and southeastern Indiana. The principal data on which this new system is based may be mentioned and discussed serially.

SCHUCHERT says: "The Ordovicic period was closed by the Utica emergence." Emergent conditions doubtless prevailed about this time, but were chiefly in evidence prior to the Utica and not after; and the Utica itself was a time of growing submergence. The extensive continental emergence which terminated the Maysville stage, and with it the Ordovician period as conceived by me, had already begun in the Mohawkian in many places within the median and western parts of the continent and continued in an oscillating manner through the Trenton, Eden, and Maysville stages. At the close of the Trenton these land conditions spread over the greater part of southeastern North America, the sea remaining perhaps only in some of the Appalachian troughs. Expansion of waters, however, set in again with the Utica, which overlaps westwardly to Cincinnati. In the Appalachian region and in central New York the Utica passes very gradually—apparently without sign of break—into the Economy zone, and this again into the Southgate zone of the Eden. But there is a decided faunal break between the typical Utica and the Economy-Southgate. The former is an Atlantic fauna the latter a Gulf of Mexico fauna. As I have explained elsewhere[2] this change

[1] SCHUCHERT, CHARLES; Bull. Geol. Soc. America, Vol. XX, 1910, p. 530.

[2] *Revision of American Paleozoic Systems*, Bull. Geol. Soc. America, Vol. XXII, 1911, p. 569.

in faunas without notable break in sedimentation was brought about by simple tilting of the land surface, the east being elevated so as to drain the Atlantic connections, the lower Mississippi area being at the same time depressed beneath sea level, permitting its flooding by waters from the Gulf of Mexico; and the latter then spread over most of the area in which the Utica shale had previously been deposited. Most of the succeeding faunas, to and in part including the Richmond of the Ohio valley, invaded from the south. To a considerable extent they resemble the preceding Mohawkian faunas in Tennessee and Kentucky, being in fact more or less modified recurrent facies of the same.

The fossils of the typical Utica are clearly of Atlantic types. They belong to the same fauna which at various other times during the Ordovician (Normanskill, Magog, and early Martinsburg) invaded Appalachian valley regions. The Utica invasion differed from the others in that it extended farther inland. At Cincinnati it is represented by the Fulton shale; and this lies unconformably on Trenton limestone. Everywhere the faunal break between the Trenton and the Utica is strong, and in many places the contact is marked by a sharp stratigraphic break. At the top, however, the black or gray shales of the Utica pass nearly always gradually into the light bluish or yellowish shales of the Economy zone. As a rule this boundary is indefinite so that we must rely on the change in fossils in drawing it at all. Often too, especially in Pennsylvania and Virginia, the colour test fails and fossil remains are exceedingly scarce; and then we are entirely unable to say where the "Ordovicic" ends and the "Cincinnatic" begins. The top of the Trenton even is exceedingly indefinite in some of these cases. So far as my own observations are concerned, the top of the Utica seems a very bad place to locate a stratigraphic boundary of high rank. To me the Utica is no more distinct from the Economy than is the latter from the Southgate; and its relations to the underlying Trenton are certainly less intimate. I have, therefore, classed the Utica as the lowest of four divisions of the Eden group. But SCHUCHERT places the Utica in the Ordovician and begins his Cincinnatic with the second division of the Eden. In other words, he seeks to draw a systemic boundary at a horizon that can not be identified except at Cincinnati and a few other places where a small hiatus separates the Economy from the Utica.

Regarding a higher contact SCHUCHERT says, "in the Cincinnati region the Maysvillian sea was apparently continued without break into that of the early Richmondian." I am unable to subscribe to this view. Throughout the Appalachian region, as well as in central Kentucky and middle Tennessee, the contact of the first Richmond bed with the underlying Maysville indicates a break in deposition; and the conditions in the Cincinnati region offer no exception to the rule. Though the boundary line is seldom conspicuously irregular and, indeed, because of the locally similar lithologic composition of the two groups of strata, is often difficult to point out in small weathered exposures, it is yet generally indicated with satisfying certainty by absence or presence in one section of beds adjacent to the contact, that are respectively present or absent in another section near the first. And when the exposure is extensive and favourably situated for observation, like the one on Sequatchie river near Jasper, Tenn., the actuality of the unconformity between them is clearly apparent to the trained eye.

In the Cincinnati region the Arnheim shale (earliest Richmond) spread over a gently warped surface and shows corresponding overlap irregularities in sequence and thickness of deposits. Moreover, as will be shown in a later section of this paper, the areal distribution of the Arnheim and, more particularly, of the succeeding Richmond deposits is vastly different from that of the preceding Maysville and Eden sediments. Evidently then, the physical diastrophic criteria do not warrant the statement that the Maysville sea continued without break into the Richmondian.

SCHUCHERT's strongest reason for associating the Eden, Maysville, and Richmond groups would seem to lie in his convictions respecting the general unity of their faunas. He says (*op. cit.*, p. 531) "on faunal grounds there is decided evidence for placing the Edenian and Maysvillian, together with the Richmondian, in the Cincinnatic system. These three series are united by about 5 per cent. of the fauna that is common to all of them, while of the Edenian species about 14 per cent. occur in the Richmondian." These figures were made up from comparisons of lists of fossils published by NICKLES,[1] who frankly admitted their probable inaccuracy. They err chiefly in crediting many species with longer ranges than they actually have. In the absence of exact information concerning their occurrence a few were included with those whose range is known to be relatively long. Others of the latter are too broadly conceived, the several occurrences being distinguishable. Finally, the majority of the remaining species comprising the 5 per cent. of the fauna that is said to be common to all of the formations of the "Cincinnatic," is made up of forms that are either too simple in structure to afford means of ready discrimination (*Dermatostroma papillata*, species of *Corinotrypa*, *Crania scabiosa*, and species of *Cyclora*, *Microceras*, *Cornulites*, *Aparchites*, and *Bythocypris*), or too variable for practical subdivision. It is only these two last sets of species that may be properly classed as common to the Eden, Maysville, and Richmond groups. Furthermore, we must not forget that some of their ancestors in the Mohawkian rocks have not been distinguished and are still known by the same names applied to Cincinnati and Richmond fossils. And some of their descendants in the Medina and Clinton rocks have been, or will be, distinguished chiefly because they are found in Silurian formations. However, counting all, I am certain that out of a total of approximately 1,000 species found in the Eden, Maysville and Richmond groups about Cincinnati, not over 2 per cent. pass from the Eden to the upper part of the Richmond; and, if I had to give their names, the number about which I could feel sure would not exceed ten species.

As for SCHUCHERT's statement that 12 per cent. of the Maysville fauna occurs in the Richmond, I can do nothing less than to deny its truth. By

[1] NICKLES, J. M.; Jour. Cincinnati Soc. Nat. Hist., Vol. XX, 1902, pp. 49-100.

stretching a point, and in a few instances disregarding differences by which the Richmond specimens may be distinguished from their earlier relatives, I might concede that, out of about 400 Maysville species, 15, or at the outside, 20 species, that is, about 5 per cent., pass across the line into the Richmond. But nearly all of these "holdovers" are of the list of long-ranging species mentioned in the preceding paragraph as either too simple or too variable to be successfully discriminated. Instead of any considerable degree of unity between the Maysville and Richmond faunas there is, on the contrary, very decided disagreement between them. The Richmond introduces at least 20 new generic types; and all the Bryozoa, of which there is a large number, and all the crinoids, starfishes and other Echinodermata, and most of the corals, trilobites, and brachiopods are strikingly different from the representatives of the same classes in the underlying Maysville formations. A greater similarity in general expression is noted when we compare the Pelecypoda, Cephalopoda and Gastropoda, but among these the degree of similarity, in so far as it bears on the question of age relations, is more apparent than real, because the specimens as a rule are too imperfect to permit of nice discrimination. Moreover, the Ordovician trend of their testimony is neutralized by an equally strong Silurian tendency when the Richmond species are compared with upper Medina and Niagaran species.

Regarding the top of the Cincinnatic, which at the same time is also the top of the Eopaleozoic, SCHUCHERT was uncertain when he published his *Paleogeography of North America* (Feb., 1910). In this work he says (p. 532), "the dividing line between the Cincinnatic and Siluric is usually drawn at the top of the Richmondian, but this delimitation will now have to be changed, as it fails to recognize a long interval elsewhere recorded. On Anticosti may be studied a complete section bridging this lost interval, and through 1,134 feet of limestone may be traced the gradual transition of the life of the highest Richmondian into that of the earliest Siluric. The Cincinnatic, therefore, can not be closed with the Richmondian, but must be continued until a considerably later period—one yet to be determined by the Anticosti record." On page 536, in speaking of the transition from the Cincinnatic into the Siluric on Anticosti he adds, "the line of division between these two systems must, here at least, ever be an arbitrary one."

Later in the same year SCHUCHERT and TWENHOFEL[1] published the preliminary results of their studies of the Anticosti section. A new series, the Gamachian, is added to the top of the Cincinnatic. It "is intended to include all American deposits later in age than the youngest Richmondian of Indiana and Ohio and older than the Anticosti series, which in the United States is thought to have its basal equivalent in the typical (upper) Medina and Edgewood stages." The fauna of the Gamachian as listed by the authors contains many species that elsewhere in America are known only in typical Richmond beds. Associated with these, however, is a considerable number of others, like *Stromatopora* sp., *Heliolites* 3 species, *Orthis flabellites*, *Rhynchonella janea*, and *Atrypa marginalis*, that have so far not been detected

[1] Bull. Geol. Soc. America, Vol. XXI., Dec. 1910, pp. 693-716.

in any of the Richmondian deposits of the interior continental basins. Judging from its fossils the "Gamachian" or Ellis Bay formation may well be younger than the Elkhorn zone at the top of the Richmond in Indiana. Very likely then, SCHUCHERT is right in placing it between the Richmond and the base of the Whiteoak sandstone of Tennessee, which corresponds to the lower part of the upper Medina of New York. But, on account of the introduction of new types of strictly Silurian aspect, and also because a large part of the formation as developed on the north shore of the island consists of sandstone, I am strongly inclined to regard the Ellis Bay formation as the first of the Anticosti group (upper Medina) and the term Gamachian series, therefore, as superfluous.

But the feature of the highest significance in this connection is the fact that the top no less than the bottom of the Cincinnatic system, as defined by SCHUCHERT, is indefinite. There is no real fauna break in the Anticosti section above the Ellis Bay formation; and the only suggestion of a physical break beneath the Chicotte seems to be at the base of the Ellis Bay. If the evidence of this break were supported by other criteria indicating a stratigraphic boundary of high grade, the combined testimony would have considerable weight against the inclusion of the Richmond and lower Medina generally in the Silurian. But as we have seen, the faunal evidence as developed in Anticosti favours much more than it opposes the alliance of the Richmond with the early Silurian.

In contradistinction to the usual indefiniteness of both the lower and the upper limits of the proposed Cincinnatic, there is at least one intermediate line that can be drawn sharply and with little trouble throughout North America. The line referred to separates the base of the Richmond from whatever Ordovician formation that it happens to overlap. In most places it marks a great hiatus. East of the Mississippi, however, the hiatus is largely occupied by Cincinnatian deposits. Even where the youngest of these intervening beds is present, the base of the Richmond is clearly indicated by physical criteria and, when local life conditions were favourable, by unmistakable faunal changes as well. In New York and Ontario this line divides the red deposits of the Queenston from the gray Oswego sandstone or, where this is wanting, from the bluish shale and sandy limestone of the underlying Pulaski; in Pennsylvania, Maryland, and Virginia it separates the Juniata from the Bald Eagle sandstone or, where this gray sandstone is absent, from some bed of the Maysville group; in east Tennessee it defines the contact of the red shale and argillaceous limestone of the Sequatchie formation[1] with any of the several Ordovician limestones on which its unconformable base may rest. The same line is readily located also on the flanks of the Cincinnati dome, but here we are guided more by easily procurable fossil evidence than by change in character of sediment. The same is largely true also in the Mississippi valley proper and no less so in the numerous areas scattered over the remaining northern and western parts of the continent, in which highly

[1] The name Sequatchie is proposed in another paper as a local designation for the deposits of Richmond age in the southern Appalachian valley.

fossiliferous Richmond deposits rest on Mohawkian or older Ordovician rocks. In fact, there is no stratigraphic boundary in American Paleozoic rocks that is more easily or more generally recognizable than the widely transgressing base of the Richmond. And yet, for no other reason than that the general aspect of Richmond faunas resembles that of the typical Ordovician rocks, certain paleontologists seek to subordinate the taxonomic significance of this datum plane to some other, often obscure, and always less certainly identifiable stratigraphic horizon![1] Next to natural relationship the quality of convenience is the prime desideratum in stratigraphic taxonomy. Let us then be reasonable and practical and accept with proper valuation those diastrophic boundaries which nature has most clearly and widely indicated.

Summing up, the proposed Cincinnatic system is not warranted by either physical or faunal criteria. Primarily, its boundaries are indefinite. They are also unnatural because they are not drawn with due regard to the principle of the introduction of geological events. Compared with other boundaries their taxonomic importance is inferior to that of the Trenton-Utica contact, which is the next beneath the base, and that of the Clinton-Ellis Bay contact near the top. Further, the association of the Richmond in the same system with the Maysville pays very inadequate tribute to the most important of all of the stratigraphic boundaries recognized between the base of the Ordovician and the top of the Silurian. Moreover, the segregation of a new system out of the middle and best known part of the Paleozoic rocks unnecessarily disturbs the present coördinate relations of the several systems; and the new system itself is particularly inferior in value to the others. Finally, the faunal and physical history of the Eden and Maysville groups is clearly a part of the Ordovician sequence of events, while the Richmond is no less distinctly the introductory stage of a new sequence. However much I might desire to do otherwise, a strict application of the principles given in my *Revision of the Paleozoic Systems* leaves no other course than to reject the Cincinnatic system.

THE ORDOVICIAN-SILURIAN BOUNDARY.

The Ordovician-Silurian Boundary in the typical British Sections.

General discussion.—The Ordovician system was proposed by Lapworth[2] in 1879 as a sort of compromise between the rival claims of Murchison's

[1] Prof. A. W. Grabau especially has been active in advocating the restriction of the term Medina to the smaller upper part of the series originally included under this name. At the same time he removes the lower Medina (Queenston-Juniata = Richmond) from the Silurian to the Ordovician. It is to be noted, however, that the frequent obscurity of the line of contact between the two parts is fully conceded and repeatedly mentioned by Professor Grabau in a paper published August 23rd, 1913, in the Bulletin of the Geological Society of America (see especially pp. 467-8.) This admission should help more than pages of argument in establishing my claim respecting the impracticalness of the Richmond-Albion boundary as the dividing line between two important systems, yes, even eras.

[2] Lapworth, Charles. *On the tripartite classification of the Lower Paleozoic rocks;* Geol. Mag., New Ser., Vol. VI Dec. II, 1879, pp. 1-15.

Silurian and SEDGWICK's Cambrian. At the time it had become evident to most geologists, especially the American, that the debatable formations between the typical parts of these two systems—that is, the formations comprised in the Lower Silurian of MURCHISON's classification—readily constituted a system by themselves. The new Ordovician system, therefore, immediately secured as adherents those who objected to the misleading qualifications "Lower" and "Upper" when applied to distinct systems. In a short time, indeed, the new term was generally adopted in America. In Europe, on the contrary, its fate seems yet undecided.

As the Ordovician and Silurian systems are based on British formations, it would be proper and desirable to begin our inquiry with a definite statement concerning the practice of British and European geologists generally in delimiting these systems. But here we are at once beset with difficulties; there is no uniformity in practice. European stratigraphers define the term Silurian in at least three ways: first, in the narrow sense commonly given it in America; second, as a broader term to include the Lower and Upper Silurian; and third, with the widest possible meaning in which it includes the Cambrian, Ordovician, and Gothlandian as subordinate groups. They vary also either intentionally or otherwise in drawing the boundaries of these groups or systems. And there is little likelihood of uniformity in practice so long as the majority of European geologists will insist on the erroneous belief that there is one common character in the faunas of the Cambrian, Ordovician, and Silurian rocks "which unites them into one great whole," and that whole the Silurian system. In America at least, no such "common character" obtains. Viewed as a whole, the American Silurian fauna is certainly more closely allied to the Devonian than to the Ordovician.

The false belief in a common faunal character that is supposed to unite the Cambrian, Ordovician, and Silurian more closely than the Silurian, Devonian, and Mississippian originated in an imperfect knowledge of the faunas, imperfect chiefly because it included little besides the trilobites and brachiopods, which then did seem to give some ground to the belief. Later it was fostered by loose fossil identifications and faulty stratigraphic correlations. But to-day, unless we completely ignore the progress in paleontologic knowledge since 1880, especially in America, it must stand discredited. This progress has shown that there are at least four well-marked Eopaleozoic faunas that are no less distinct from each other than are the Silurian, Devonian, and Mississippian.

Another point that the European geologists must concede before they can hope to fully work out the geological history of their own lower Paleozoic sections, especially those geologists who speak of the Baltic and Bohemian sections as complete records of marine sedimentation during the Cambrian, Ordovician, and Silurian periods, is that the American sedimentary record is vastly superior in certain parts to the European. Our Appalachian Valley record is superior, not only in the aggregate thickness of deposits but also in that it contains great and well illustrated chapters that are wholly missing or but imperfectly represented in European sections. And when I mention greater thickness I do not refer merely to volume of deposits without regard to whether they are of clastic or other origin, but I have very ful' in mind the probable length of time consumed in their making. On the othe, hand, I deem it more than probable that the British and Bohemian sections contain beds representing minor ages at least that have not yet been recognized in America. But that would only emphasize the point I wish to make, which is, that while the American Paleozoic sedimentary record is the fullest known, there is none in any country that is even approximately complete. Each requires to be read in the light of the others. Even then, much must remain unknown because many parts of the stratigraphic and faunal records are buried in inaccessible situations.

Local environment of observers is a more potent factor in the shaping of their opinions than one would ordinarily believe. For instance, the Germans, who are naturally given to minute discrimination, are satisfied with the Murchisonian Silurian because the lower Paleozoic rocks are very poorly developed in their country. The Russian and Scandinavian geologists, for similar reasons, seem unwilling to recognize the Ordovician as distinct from the overlying Silurian, though somewhat grudgingly conceding the Cambrian system. In Britain, where the lower Paleozoics are more fully represented, there are some geologists at least who divide Murchison's Silurian into three systems. Limited native opportunities to study these old systems, especially in continental Europe, doubtless is largely responsible for the prevailing lack of appreciation of the results of American geologists whose field of labour is not only broader and better displayed but contains also a much more complete sequence of marine deposits.

The same principle is illustrated on a smaller scale by geologists in this country. Thus, WORTHEN, who knew the Helderbergian only as developed in the Mississippi valley, could not convince himself that this series is wholly distinct from the Niagaran. Comparison of faunas alone, particularly when this information is gathered chiefly from books, can not give the student a proper conception of age relations. The real significance and importance of the differences noted is impressed on his mind only when he finds the fossils themselves in a relatively complete sequence of deposits. There is no experience quite so convincing as the finding of thousands of feet of sediments between two fossil zones that had previously seemed closely related.

Except the graptolites, whose zonal occurrence has been admirably worked out by LAPWORTH, the detailed sequence of Ordovician and Silurian faunas in the British Islands is much less completely determined than in America. Stratigraphic correlation, therefore, has been carried out in greater detail here than there; and it is to be observed that the graptolites have contributed only to a very limited extent to the data on which the correlations in the interior American areas are based. The graptolites are largely confined to shales and sandstones in certain areally narrow bands outside of the limestone-depositing basins. These shale areas, in which the graptolites built up a faunal sequence of their own, are provincially distinct from the interior areas in which limestone deposition predominated; and the several units in each seem, as a rule, independent in age from those in the other. Correlations between the two, therefore, have been rendered possible only by occasional overlap interfingering of the two sets of deposits in areas alternately captured by the waters of the two provinces.

The discovery of these overlaps is of great importance in Ordovician stratigraphy because they have shown that even the justly lauded graptolite zones of LAPWORTH are but a coarse standard of stratigraphic measurement. Considering the great thickness of limestone formations that intervene between some of these overlapping graptolite zones in the Appalachian valley, it seems positively assured that the sedimentary record in those troughs in which the stratigraphic sequence is built up solely by graptolite-bearing shaly deposits, is far from complete. Take, for instance, the interval between the *Nemagraptus gracilis* zone of the Glenkiln shale and the zone of *Climacograptus caudatus* in the lower part of the Hartfell shale, which overlies the Glenkiln shale: in America the former is recognized very satisfactorily in the Normanskill shale of New York, in the Athens shale of Tennessee and Virginia, and in the Stringtown shale of Arkansas and Oklahoma. In Tennessee the *Nemagraptus gracilis* zone lies in the lower half of the Blount group of the Chazyan, while *Climacograptus caudatus* is found in New York, in beds that must lie near the boundary between the Trenton and Black River groups of the Mohawkian. The two zones, therefore, seem to be separated by over 2,000 feet of deposits, most of them limestone. Even greater time values are suggested by our sections for the intervals between Lapworth's graptolite zones beneath the Glenkiln. Those separating the post-Glenkiln graptolite zones, however, seem to indicate intervals of relatively shorter duration. This is suggested not only by smaller thicknesses of beds but also by the greater faunal similarity of the successive zones.

As a rule the typical Bala and Caradoc beds of England, in which graptolites are few, are synchronized with thinner formations like the Glenkiln and, more particularly, the Hartfell shales of Scotland in which graptolites are very abundant and little else is found. The latter are sometimes viewed as deep sea deposits and their relatively small thickness is thus supposed to be explained, the former being regarded as being laid down in shallow water. But may it not be that these British graptolite-bearing series represent repeated submergences of particular strait-like channels? Indeed, submergence of these channels may have occurred chiefly at times when adjacent basins were emerged. Land and water oscillation with consequent shifting of areas of marine deposition is quite certainly indicated in the Appalachian region. It is notable also in the Ouachita region of Arkansas and Oklahoma, and as the diastrophic history of these American areas seems comparable in general with that of Great Britain, similarly oscillating deposition is suggested also.

The condition of oscillating deposition and shifting seas is indicated especially about the close of the Ordovician and the beginning of the Silurian in Great Britain. It is suggested by numerous published faunal lists which, if they were attributed to American beds, would be explainable only on the assumption of careless collecting or erroneous correlation of beds. But these mixed faunal lists would be easily accounted for if we knew that locally developed thin wedges or lenses of older or younger beds, as the case may be, were not recognized as such by the collector. Such small lenses are very common in American sections and it would seem strange indeed if they did not occur frequently also in the British sedimentary record. But a study of geological literature pertaining to Great Britain has brought out very few instances of the kind.

An excellent example of what I refer to in speaking of "mixed faunal lists" is given on pages 948 and 949 of the last edition of GEIKIE's *Textbook*. Running through this generalized list of Bala and Caradoc fossils we find among a large number of regular Ordovician types the following: *Alveolites*, *Cyathophyllum*, *Favosites*, *Heliolites interstinctus*, *Fenestella*, *Glauconome*, *Ptilodictya*, *Orthis (Dalmanella) elegantula*, *O. porcata*, *Leptæna rhomboidalis*, *Atrypa marginalis*, and *Meristella*. To these we may add *Palæocyclus*, *Lindstræmia*, *Plasmopora conferta*, *Favosites asper*, *F. gothlandicus*, *Anoplotheca hemispherica*, *Atrypa reticularis*, *A.? imbricata*, *Whitfieldella tumida*, *Spirifer crispus*, *Rhynchotreta cuneata*, *Stricklandinia* sp., and *Bilobites biloba*, taken from lists published by PEACH and HORNE.[1] and MARR.[2] In America none of these generic and specific types occurs beneath the Richmond and most of them are never seen beneath the upper Medina or the Clinton. *Zygospira (Catazyga) headi* is the only species in GEIKIE's list that may be said definitely to suggest the Richmond. As for the other Bala and Caradoc species in these three lists, a few might occur in the Maysville group of the Cincinnatian but the remainder would seem out of place on this side of the Atlantic above the Mohawkian. If the latter typical Ordovician fossils actually occur associated in the same bed with the above mentioned Silurian types then there is nothing to do but to adjust our conceptions to the fact. But, considering other possibilities, doubt as to such occurrence seems justified until the disconcerting association is positively verified.

American correlatives of British Ordovician and Silurian formations.—As defined by LAPWORTH the Ordovician system includes the strata "between the base of the *Lower Llandovery* formation and that of the *Lower Arenig*." The lower boundary is not of immediate consequence here. Of it I shall say at this time only that if we are to recognize but two Eopaleozoic systems, that is, two beneath the typical Silurian, then it seems altogether proper to draw the dividing line between them at the base of the Arenig. However, if we divide the Eopaleozoic into four systems as advocated by me[3] then the Arenig would fall into the third or Canadian system, while the Ordovician would begin in Great Britain with the Llandeilo or the Llanvirn, and in America with the St. Peter series.

Regarding the upper boundary of the Ordovician, LAPWORTH says it

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[1] *The Silurian rocks of Britain*, Vol. I. Scotland, Mem. Geol. Survey United Kingdom, 1899.

[2] MARR, J. E. *The classification of the Cambrian and Silurian rocks*, 1883.

[3] *Revision of the Paleozoic Systems.*

should be drawn at the base of the Lower Llandovery. But what does this mean in American stratigraphy? Perhaps we may reach a conclusion best by first approaching the line from the bottom. In England and Wales the in part equivalent Bala and Caradoc, both formations of considerable thickness, underlie the Lower Llandovery. The fauna of the lower and middle Bala, measured by American standards, seems to be unquestionably pre-Cincinnatian and both divisions may be pre-Mohawkian. The lower part most probably corresponds to our upper Chazyan, that is to the whole or to some part of the Blount group of east Tennessee.[1] The middle Bala agrees best with the Appalachian facies of our Black River as developed, for instance, in the Liberty Hall limestone of Virginia[2] and the Chambersburg limestone of Pennsylvania. Possibly it is somewhat older and, like the lower Bala, still to be correlated, in part or whole, with the Blount group. But all of these Atlantic faunas are singularly persistent in type, so that it would not be safe without further study to decide this point definitely. When we come to the upper Bala the case is again doubtful, but now the doubt tends in the opposite direction. Fossils do not seem to be very plentiful; and some of the lists include names that led to foregoing remarks about possibly mixed collections. MARR, for instance, lists *Atrypa imbricata* and a species of *Strickland inia* as found in these beds, but neither would be a proper constituent of an American Ordovician fauna.

In Scotland the Hartfell shales are placed at the top of the Ordovician. LAPWORTH divides this body of shale into two groups, and recognizes three rich graptolite zones in the lower and two, separated by an unfossiliferous mudstone, in the upper. The lower group contains some species that have been identified also in America. Here most of them are confined to various horizons supposed to be of the age of the Trenton group. Others have been seen in this country as yet only in the older Normanskill shale, while the remaining two or three species are from shales now referred to as Utica. The lower Hartfell zones may thus be somewhat loosely correlated with our Trenton.

The graptolites of the upper Hartfell zones suggest two faunas in America. The Polk Creek shale of Arkansas and Oklahoma probably contains more species reminding of upper Hartfell forms than any other of our graptolite-bearing formations. In this shale we find *Dicellograptus complanatus*, which is characteristic of the lower of the two upper Hartfell zones. In America, however, this graptolite ranges with very slight modification through the whole of the Polk Creek shale. Apparently the same species is found also in the Sylvan shale of Oklahoma. Though the Sylvan shale seems to be much younger than the Polk Creek shale, a comparison of their respective faunas shows that besides *Dicellograptus complanatus*, also *Diplograptus crassitestus*

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[1] *Revision of the Paleozoic Systems*, Bull. Geol. Soc. America, Vol. XXII, 1911; correlation chart No. 1, also pp. 379, 382, 567, 576, 627.

[2] The age of the lower part of the Liberty Hall limestone is still in doubt. If we may rely on the general aspect of its fossil contents the basal part of the formation is of late Chazyan rather than Black River age.

and *Climacograptus ulrichi* are represented in both by indistinguishable species or close varieties.

Perhaps the most important of the facts brought out by comparison of the British upper Hartfell graptolites with American species is the presence of *Dicellograptus complanatus* var. *ornatus* in the upper part of the Polk Creek shale in Arkansas. This well-marked variety is found in Scotland only in the upper part of the upper Hartfell, that is, in the *Dicellograptus anceps* zone. If this variety actually holds the same stratigraphic position in the two countries, and if *Dicellograptus complanatus* appeared about the same time in both places, then we might say that the essential equivalence of the Polk Creek and the upper Hartfell shales is assured. At the same time the upper limit of the Ordovician would be determined, in at least one American section, the same as it is in Britain.

Though the associated graptolites are perhaps less diagnostic than these dicellograptids, their evidence seems confirmatory. Compared with British species, the six or eight *Diplograptidae* of the Polk Creek shale, though perhaps in no case exactly identifiable with forms described by ELLES and WOOD, would yet seem not out of place in either a lower or an upper Hartfell zone. Some of them suggest even later Birkhill species. Besides the *Diplograptidae* and the previously mentioned dicellograptids the Polk Creek shale contains also a *Leptograptus* allied to the long-ranging *L. flaccidus*, a third *Dicellograptus*, reminding in this case of *D. morrisi*, and a *Retiolites*. The last three have been found only in the lower third of the formation.

Judging solely from internal faunal evidence, it would seem, therefore, that the base of the Polk Creek shale can not be older than lower Hartfell. That it is indeed younger and probably altogether upper Hartfell is indicated by the fact that the range of *Orthograptus quadrimucronatus* entirely underlies the Polk Creek shale. In the Ouachita region this well marked graptolite is found in shale and limestone beds in both the lower and upper parts of the Big Fork chert, a chert-producing limestone formation 500-700 feet thick.[1] In Britain *O. quadrimucronatus* is confined to the upper (*Pleurograptus linearis*) graptolite zone of the lower Hartfell and in Canada to shales that have been quite generally referred to the Utica.

Accepting the Polk Creek as the American representative of the upper Hartfell, we may reasonably go a step farther and assume that the Silurian begins in the Ouachita section with the succeeding Blaylock sandstone. This sandstone attains a thickness of 1500 feet, but is confined to the southern ranges of the Ouachita mountains, the section elsewhere showing a hiatus in

[1] Locally in Arkansas the upper 50 feet or more of the *O. quadrimucronatus* zone consists entirely of siliceous shale or slate. In such instances the lower boundary of the Polk Creek shale has been mapped so as to include a part of this zone. It seems well to add here that certain of the graptolite collections credited to the lower part of the Polk Creek shale remind of lower Hartfell rather than upper Hartfell zones. In fact the various local collections from shales 10-50 feet above the top of the Big Fork chert are often so different that it does not seem possible that they all represent the same zone. It may well turn out, therefore, that older graptolite zones than those of the upper Hartfell are locally represented in the siliceous black shales that it was found convenient to include in the Polk Creek shale rather than in the underlying Big Fork chert.

its place. Not uncommonly, too, there is a black earthy conglomerate with chert pebbles at the base of the Blaylock. The basal conglomerate together with the facts (1) that the Blaylock is restricted to certain troughs, and (2) that the underlying Polk Creek shale is distributed generally through the Ouachita area, makes it certain that decided warping and erosion had occurred during the interval immediately succeeding the deposition of the Polk Creek shale. It seems, then, that this region was affected by conditions not unlike those which prevailed in Britain between the close of the typical Ordovician and the beginning of the typical Silurian.

Unfortunately neither the Blaylock sandstone nor the overlying Missouri Mountain shale have so far provided any satisfactory organic remains. At one locality in the Caddo Gap quadrangle a few remains of small *Diplograptidæ* were noted but these were too poorly preserved to be identified specifically. Though no sign of *Monograptidæ* was observed, their absence may well be due to causes affecting geographic distribution. On the other hand the diplograptids were thoroughly cosmopolitan at this time, so that it is no more extraordinary to see such species in the Blaylock than in the early Silurian Birkhill shale of Scotland and the Llandovery of England.[1]

The Ordovician-Silurian boundary in the interior areas.

Having reached a fairly satisfactory conclusion regarding the position of the Ordovician-Silurian boundary in the Ouachita region of Arkansas, we are ready to consider the problem in the interior basins. Here, however, the criteria are much less simple and the solution of the questions correspondingly involved. To begin with, the faunas of the interior American deposits adjacent to the boundary are too greatly unlike the British non-graptolite fossils to give wholly satisfactory clues to their age relations. If we were quite sure that the Silurian types in the lists of British late Ordovician fossils mentioned on page 619 owe their inclusion in the faunal lists to error, we might proceed with some confidence in the result. But we are not certain of this, hence it is necessary for the present to assume that either many fossils which are never seen in this country beneath the Medina or the Clinton began earlier in Britain, or that the base of the Silurian has been drawn in America at a lower plane in the stratigraphic column than in the British sections. The latter alternative, however, seems the less probable of the two

[1] Since this paper has been put into type a small collection of graptolites from the Blaylock sandstone of Arkansas, collected by Mr. H. D. MISER of the U. S. Geological Survey, has been placed in my hands for determination. This collection proves to be of great importance and a source of considerable satisfaction, because it contains no less than five species described from the Birkhill shale, namely, *Monograptus distans* Portlock, *M. gregarius* Lapworth, *M. argutus* Lapworth, *Dimorphograptus decussatus* Elles and Wood, and *Glodiograptus perlatus* Nicholson. Three other species are represented by specifically undeterminable specimens, one being a *Monograptus* allied to *M. fimbriatus* Nicholson, the second a species of *Dictyonema*, the third altogether unrecognizable. With this additional evidence, then, the Silurian age of the Blaylock sandstone seems incontestably established. It assists also in proving the post-Ordovician age of the Richmond, because there is no reason to doubt that the Blaylock represents the lower as well as the upper division of the Medinan series.

because the great majority of the Caradoc and Bala fossils are of genera and species that are found here only in Mohawkian formations; and, excepting the previously mentioned, assumed Silurian forerunners, very few, if any, of the remaining Caradoc and Bala fossils suggest American formations as high even as the Maysville group of the Cincinnati section. If the uppermost fossiliferous zones of the Caradoc are indeed younger than the Eden of this country, then we would again be obliged to assume that Ordovician fossils like *Trinucleus*, *Ampyx*, and *Agnostus* lived to a later time in Europe than in America. In American formations, as a rule, the genus *Trinucleus* is not seen above the Eden, particularly in the vicinity of Cincinnati and in the middle Appalachian region, while *Ampyx* and *Agnostus* are wholly unknown above the lower half of the Trenton.[1]

Considering the diverse tendencies of the fossil evidence in seeking to correlate the supposedly late Ordovician beds in, say, Kentucky-Ohio and New York sections with the subdivisions of the Caradoc and Bala series of Britain, it is evident that detailed results are as yet impossible. Still, generalized correlations are quite practicable on the basis of fossil evidence alone. Comparing the general aspect of Caradoc and Bala faunas with interior American fossil associations, there can be no reasonable doubt that our Mohawkian epoch, at least, is represented in the British series mentioned. Depending chiefly on *Trinucleus*, we may justly include the Eden group among the American correlatives of the upper part of the Caradoc-Bala series. But there is absolutely no warrant in the fossils for adding either the upper division of the Maysville group of the Cincinnatian or any part of the succeeding Richmond group of formations to these correlatives. Approximately 1,000 species of fossils from these groups are wholly unknown in Britain. On the other hand, if we may depend on the fossil evidence, the base of the Lower Llandovery, which is the first of the Silurian formations in Britain, can not be older than our Medinan and most probably is

[1] In north-central New York and in the Province of Quebec *Trinucleus* cf. *concentricus* is frequently found in the lower part of the Pulaski shales. Thi Trinucleus zone is clearly younger than the top of the Eden at Cincinnati. Approximately 200 feet above it, that is in the lower part of the overlying Oswego sandstone, at Lorraine and along Salm[illegible] ver in New York, are beds which contain an association of pelecypods, like *Whitfieldsia* [illegible] *a*, *Orthodesma nasutum*, and *Ischyrodonta unionoides*—that is found at Cincinnati on[illegible] the basal part (Bellevue member) of the McMillan formation. From this we would naturally suppose that the intervening beds correspond to the lower or Fairview formation of the Maysville group in Ohio, but the fossil evidence, though abundant, is not at all clear on this point. Besides, most of the species found in this upper horizon occur also in the upper half of the underlying Pulaski beds. Evidently some kind of barrier separated the Cincinnati or Gulf facies of the Fairview, which is recognizable in the east as far at least as Toronto, from another facies of similar, or more likely later, age that invaded from the Atlantic and established itself in central New York and on the other side of Adirondackia in southwest Quebec. As to the Pulaski *Trinucleus* zone itself the evidence in hand suggests two rather widely different conclusions: (1) that it falls into the hiatus commonly indicated between the top of the Eden and the base of the Maysville in the vicinity of Cincinnati, or (2) that the greater part if not the whole of the Pulaski wedges into the similarly indicated hiatus between the Fairview and McMillan divisions of the Maysville group as developed in the Ohio valley. At present the latter of these alternations appears the more probable.

younger than the lower or Richmond half. Accordingly then, we conclude that the upper beds of the Maysville group and at least the greater part of the Richmond group, are unrecognizable and probably entirely absent in the British section.

The Medinan, and perhaps only late Medinan, age of the Lower Llandovery is determined in two ways: first, by direct comparison of its fossils with Medina faunas, and second, through elimination indicated by agreement between the fossils of the Upper Llandovery and those of our Clinton. Unfortunately, the *Monograptidæ*, which help so materially in differentiating the Silurian in Europe, are very poorly represented in America. In fact, only two species of this family have been found in America; and both of these delayed their advent till well up in the Clinton. Evidently the American epicontinental Silurian basins were not favourably situated with respect to Atlantic currents. A few of the then cosmopolitan *Diplograptidæ* and *Dicellograptidæ* are preserved in certain of our Richmond shales and sandstones (the Arnheim division of the Richmond group in Ohio, the Maquoketa shale of the Mississippi valley, the Sylvan shale of Oklahoma, the Blaylock sandstone of Arkansas, and the Thebes sandstone of Illinois), but even these were not generally distributed; and they soon died out entirely.

Viewed from the standpoint of stratigraphic correlation the Richmond *Diplograptidæ* and *Dicellograptidæ* offer no conclusive evidence. In both of these families of graptolites relative stability of specific characters had been attained in the later ages of the Ordovician. Moreover, being pelagic animals, they were perhaps less affected by the physical disturbances which prevailed during the transitional ages between the Ordovician and Silurian than most other, particularly shallow-water, bottom-dwelling, classes of marine organisms. Whatever the reason, it is a fact that the early Silurian species of *Dicellograptus*, *Climacograptus*, and *Diplograptus* are difficult to distinguish from middle to late Ordovician species of the same genera. In any event there is no general peculiarity that may be seized upon as a criterion in separating the Silurian species of these genera from their Ordovician ancestors.

The truth of these statements must impress itself upon any one who will try to identify his specimens from the excellent figures and careful descriptions of the British Silurian and Ordovician species of these genera published in ELLES and WOOD'S monograph. Under the circumstances, the admission of close alliance between the Richmond species of graptolites and certain Ordovician species should not be construed as materially weakening the argument by which the Richmond is referred to the Silurian side of the boundary. That they can be distinguished at all is a fact of some consequence; and that most of them may be is shown by RUEDEMANN'S studies who described three of the Richmond species which I sent him for determination as new.[1] My own

[1] RUEDEMANN, RUDOLPH. *Graptolites of New York*, Pt. 2, New York State Mus. Mem. II, 1908. In this work Dr. RUEDEMANN describes the new species *Diplograptus crassitestus*, *Climacograptus ulrichi*, and *Climacograptus mississippiensis*. *Dicellograptus complanatus* is doubtfully identified, while *Diplograptus peosta* and *Climacograptus putillus* are regarded as conspecific with Trenton and Eden forms.

study of these Richmond graptolites has convinced me that their relations are quite as near to species found in the Silurian Birkhill shale of Britain as to Ordovician forms. The Richmond being, according to my views, intermediate in position between the Hartfell and Birkhill shales, this determination of the affinities of the Richmond graptolites seems normal.

Proceeding with the discussion of the age of the Lower Llandovery, the probability already arrived at, namely, that the Richmond graptolites suggest a somewhat greater age, is substantiated by the non-graptolitic fossils. As listed by British authors the Lower Llandovery includes species of *Heliolites, Lindstræmia, Ptilodictya*(?) *Plœrapidella doringiæ, Fenestella, Phænopora constellata, Lingula cuneata, Dinobolus davidsoni, Meristella angustifrons, Atrypa reticularis, A. marginalis, Anoplotheca, hemispherica Pentamerus undatus, Stricklandinia lens, S. lirata, Rhynchonella decemplicata*, etc. A fauna like this, measured by American standards, could not be older than upper Medina. According to my interpretation of the Anticosti section it would be late Anticosti. Compared with Appalachian faunas, *Atrypa reticularis* and *Anoplotheca ? hemispherica* would suggest a Clinton source for part of the material. However, the Anticosti fauna doubtless is a truer standard for comparison with the Lower Llandovery than any of the interior American faunas of the period, and, as certain species doubtless appeared earlier in the Anticosti section than elsewhere in America, it is not unlikely that the important guide fossil for the lower Clinton in the Appalachian region—*Anoplotheca hemispherica* appeared in British waters as early as the Albion stage[1] of the Medinan. Still, a critical study of the Lower Llandovery specimens referred to *Anoplotheca hemispherica* is desirable before the suggested pre-Clinton appearance of the species is to be accepted as established.

Many of the Lower Llandovery fossils are said to pass into the Upper Llandovery. In the latter, however, they are associated with corals like *Syringopora bifurcata, Zaphrentis stokesi, Ptychophyllum linnarsson, Omphyma turbinatum, Favosites forbesi*, and *Plasmopora conferta*, also with an abundance of *Pentamerus oblongus, Rhynchotreta cuneata*, and other fossils of like tenor that seem to establish the age of the containing beds as Clinton, and in part at least as late Clinton.

Considering every phase of the problem, including the composition and sequence of the faunas, the thickness and character of the deposits, and all such data which have a bearing on the diastrophic history of the time, the following conclusions seem reasonably justifiable:

(1) That the top of the Polk Creek shale of Arkansas and Oklahoma corresponds essentially to the top of the Hartfell shale of Scotland; (2) that the Polk Creek shale as a whole probably includes some beds at the base that are of lower Hartfell age, but that the greater part of the formation is to be correlated with the upper Hartfell; (3) that the Blaylock sandstone and probably the overlying Missouri Mountain shale correspond in general to

[1] The need of a distinct formational name for the upper Medina having become apparent in the preparation of the Niagara Falls folio in course of publication by the U.S. Geological Survey, Dr. J. M. CLARKE has coöperated by suggesting the term Albion.

the lower and upper divisions of the Birkhill shale of Scotland and to the Llandovery of England; (4) that the Bala and Caradoc series of Britain, with the probable exception of undiscriminated lenses at the top which contain fossils ordinarily indicative of Silurian ages, correspond to our Mohawkian series plus the upper part of the underlying Chazyan and the Eden group of the overlying Cincinnatian; (5) that the lower Bala of Marr, the Llandeilo of MURCHISON (as defined by GEIKIE), and the Glenkiln shale of Scotland are of upper Chazyan (Blount group of Tennessee) age; (6) that the Maysville group of the Cincinnatian and the Richmond group of the Medinan are either missing entirely in Britain or their unrecognized representatives are poorly and probably only locally developed, and thus have been included in the top of the Caradoc or possibly in the basal part of the Llandovery; (7) that the fossiliferous Lower Llandovery corresponds chiefly to our Albion (upper Medina) and the Upper Llandovery to our Clinton.

The Base of the Silurian in the Interior Areas of America.

Introductory statements.—With two groups of formations—the Maysville and the Richmond—apparently belonging in the hiatus that is frequently indicated in Britain by an unconformity between the Caradoc-Bala series of the Ordovician and the Llandovery series of the Silurian, it remains for the Americans themselves to decide just where the boundary between the two systems is to be drawn in America. For more than fifty years there has been absolute accord among American geologists respecting the location of this boundary in the standard New York section. There was some misunderstanding regarding the stratigraphic position and equivalents of the Oneida conglomerate, which was generally believed to lie at the base of the Silurian and thus beneath the Medina. But this error was corrected when we learned that the Oneida belongs at the top of the Medina if, indeed, it is not, as VANUXEM long ago contended, the basal deposit of the Clinton.

With the transposal of the Oneida from the base to the top of the Medina the "gray sandstone of Oswego," which had been supposed to be the same as the Oneida, again resumed its independence. Without adequate consideration of the facts in the case the Oswego sandstone, as it is now generally known, was referred by HARTNAGEL to the base of CLARKE and SCHUCHERT's Oswegan series. This series or group being the lowest of the major divisions of the Silurian, the Oswego sandstone was at the same time given the distinction of being the basal deposit of the Silurian system. Before we discuss the question of the proper disposition of the Oswego sandstone, it is to be said that this formation had nothing to do with the development of the long-prevalent conception of what constitutes the base of the Silurian in America. The Oneida did have something to do with it, but only on the basis of the erroneous belief that placed it at the bottom of the Medina and correlated it with the Oswego sandstone. The true equivalent of the Oneida in the western district of New York was not recognized as such by HALL, while the Oswego sandstone was exposed in New York only in VANUXEM's district. After all, there it was the Medina itself that determined the question of the base of the Silurian in HALL's mind; and DANA, like all other geologists of the past half century, simply accepted HALL's view.

Excepting certain basal beds now referred to the formation, the Oswego sandstone has so far proved practically unfossiliferous. This is true not only for New York, but also in central Pennsylvania, where the corresponding formation (Bald Eagle sandstone of GRABAU) attains much greater thicknesses. In both areas, however, the rock immediately beneath contains organic remains in abundance. Compared with the Cincinnati section, the underlying fossiliferous bed in Pennsylvania corresponds, as is indicated by the fossils, to the *Orthorhynchula linneyi* zone at the top of the lower or Fairview formation of the Maysville group. In fact the guide fossil of this zone was observed in argillaceous sandstone at many places in Pennsylvania either directly or but a few feet beneath the base of the Oswego. Though flat, black pebbles are frequently seen in and just above the *Orthorhynchula* zone no convincing evidence of a stratigraphic break has been observed. In any event, if there is a hiatus at this horizon it is too obscurely indicated to be readily apprehended. Still, the abrupt extinction of the *Orthorhynchula* fauna suggests termination of ordinary marine conditions. Possibly the Oswego sandstone is a land deposit; or, perhaps, river silts laid down in a shallow bay. Whatever its origin may have been, it is thought to have been connected with sea-withdrawal, because decided marine restriction is indicated throughout southeastern North America at the close of the Fairview age. It is only in the vicinity of Cincinnati and probably in the Province of Quebec that all of the second or McMillan half of the Maysville epoch is represented by deposits containing a marine fauna.

No deposits whatever are contained in the Appalachian sections south of Pennsylvania that might be of the age of the McMillan. Throughout this great region the Fairview division of the Maysville, which likewise is absent over large areas, is succeeded by rocks of either Medinan or Clinton age. To the north, however, in central Pennsylvania and in western and central New York, we do find a mass of rock between the Fairview—possibly represented in New York by the Pulaski (see note, page 623)—and the Richmond (Juniata and Queenston) stage. This intervening rock is the Oswego sandstone. Chiefly on account of its stratigraphic position the Oswego is correlated with the McMillan. Its geographic location also is such that it may very well be brought into connection by way of the Allegheny basin with the McMillan remnant of the Cincinnatian sea.

This correlation finds strong corroboration in various facts recently observed in central New York. Following Salmon river up-stream from Pulaski to Salmon River falls the section passes through some 200 or 300 feet of shales and sandstones belonging to the Pulaski formation. Fossiliferous ledges, usually crowded with pelecypods, brachiopods, and bryozoa, occur very commonly in the lower half of the Pulaski. In the upper half, however, the barren intervals become increasingly thicker, though the relative abundance of the organic remains in the fossiliferous ledges themselves is not materially lessened until the base of the falls is reached. Though loose fragments indicate still higher fossiliferous layers, the last of those observed in place occurs about 8 feet above the water-level at the foot of the falls. Before reaching this point, however, it is evident that the section has ascended into the base of the zone of prevailing sandstones to which the term Oswego sandstone is properly applicable. Indeed, I refer all the beds exposed along the river to and a short distance below Bennets Bridge to the Oswego. According to this view the base of the formation must lie at least 50 feet beneath the lowest bed shown at the foot of the falls.

The following interesting faunule was found at the bottom of the river just below the new power-dam at Bennets Bridge: *Byssonychia radiata*, *Whiteavesia corrugata*, *Othodesma nasutum*, *Ischyrodonta unionoides* (? *I. curta* Conrad sp.), *Lyrodesma* cf. *poststriatum*, *Archinacella* sp., *Cyrtolites ornatus*, and *Rafinesquina* aff. *alternata*. All of these species were seen again about midway between the power dam and the falls, in thin-bedded sandstone some 20 to 30 feet higher in the section. Here the collections made by Prof. A. Foerste and the writer included the following additional species: Columnals of undetermined crinoid, *Rafinesquina squamula mucronata*, *Pholidops* cf. *cincinnatiensis*, *Catazyga erratica*, *Cleidophorus planulata*, *Modiolopsis modiolaris*, *Whiteavesia* aff. *cincinnatiensis* and *Orthoceras* sp. undet.

The specimens found in the highest fossiliferous layers observed in the cliff at Salmon River falls are not very good, but may be identified provisionally as follows: Rounded crinoid columnals, *Iocaulis*? sp., several undetermined trepostomatous Bryozoa, *Byssonychia radiata*, *Modiolopsis* sp. (related to *M. milleri* and *M. concentrica*), numerous small Pelecypoda suggesting *Modiolopsis faba* and species of *Psiloconcha*, *Ctenodonta* and *Cleidophorus*, *Orthoceras* sp. (has strong transverse striations) *Endoceras* sp., and fragments of *Isotelus*.

Except that it passes very well for a Maysville fauna, the last contains nothing more definitely characteristic. The other two collections however, are much more promising, most of the species being found at Cincinnati and having a fairly restricted vertical range in the Ohio section. Judging from their position in the Cincinnati section, relying, however, chiefly on such narrowly confined species as *Ischyrodonta unionoides*, *Whiteavesia corrugata*, and *Orthodesma nasutum* the age of the containing beds should be the same as that of the Bellevue member of the McMillan formation, that is, oldest McMillan. Although this correlation is clearly indicated by the fossil evidence I yet hesitate to accept it as unquestionable. The doubt arises from two facts (1) because the evidence on which the upper part of the Pulaski formation might be decided to be of the age of the Fairview is not at all satisfactory, and (2) because it appears from the work of Professor Foerste that most of the species associated on Salmon river in New York with *Ischyrodonta unionoides* range through thousands of feet of shaly sandstones at Three Rivers in the Province of Quebec, extending indeed to the base of the beds containing an early Richmond (Waynesville) fauna.

The latter fact suggests three possibilities: First, that this well-marked fauna represents the north-middle Atlantic facies of the Maysville fauna and that it persisted in this realm with little change from the beginning of the Fairview age to [illegible] close of the McMillan age. Under this interpretation the great thickness of beds involved leads to the assumption that the Atlantic fauna had access to the late Ordovician basins in southwestern Quebec throughout the time occupied by the deposition of the Pulaski shale and the Oswego sandstone in New York, and of the two Maysville formations, with their generally very different southern faunas, in Ohio.

The second possibility—deduced by the purely paleontologic method—implies that the *Ischyrodonta unionoides* fauna existed in both the Atlantic and Gulf of Mexico basins, and that it invaded New York and Quebec from the former, and the Cincinnati region from the latter. It implies, further, that the narrow zone to which this fauna is confined at Cincinnati is either the full time equivalent of thicker beds in central New York and of the much greater thickness of beds in Quebec that contain the same guide fossils, or that the last represents the full depositional record of this age and the others merely later southwestwardly overlapping parts. Under this interpretation we would have to assume either of two conditions: (1) that the whole of the series in Quebec containing species of the *Ischyrodonta unionoides* fauna is of the age of the basal part of the McMillan of Ohio; or (2) that nearly the whole of it represents deposition in Quebec when emergent conditions prevailed at Cincinnati and hence, that by far the greater part of the series is older than the McMillan and younger than the Fairview—in other words that the hiatus between the Fairview and the McMillan in the Cincinnati section is represented in Quebec by thousands of feet of deposits. Another necessary assumption, under either of these alternative conditions, is that the major parts of the Osewgo sandstone and the McMillan formation are unrepresented by deposits in Quebec.

The third possibility assumes that the *Ischyrodonta unionoides* fauna was confined to the Atlantic realm and that it invaded the continental basins only subsequent to the Fairview. It assumes, further, that the beds in Quebec which contain this fauna, likewise the Oswego sandstone of New York and Pennsylvania, are essentially equivalent to the McMillan plus the perhaps undeterminable stratigraphic value of the hiatus that is known to separate the McMillan from the Fairview in the Ohio Valley. Under this interpretation, which seems the most probable and is adopted provisionally, the layers in the basal part of the Oswego sandstone containing the *Ischyrodonta unionoides* fauna must represent an early westward invasion of the Atlantic fauna that extended to Cincinnati about the beginning of the southern McMillan invasion of the Ohio Valley. Subsequent to this faunal transgression the area receiving deposits of McMillan age was divided into three parts by shallowing, a[illegible]ps emergence, of a median portion which thereafter received only [illegible] deposits. These Oswego shallows and sand flats apparently served eff[illegible]y in separating the Atlantic fauna of the time in the Quebec province from the more varied and otherwise very different Gulf faunas whose remains we find so abundantly in the typical McMillan deposits of the Cincinnati region.

If we adopt either the first or the third of these possible correlations the Ordovician, or at least pre-Richmond, age of the Oswego sandstone must be accepted as established. However, under the second interpretation it is still remotely possible that the middle and upper parts of the Oswego are younger than the McMillan. But this would necessitate the assumption that the fossiliferous lower part of the Oswego is separated from the overlying unfossiliferous parts by a break and hiatus corresponding to the major portion of the McMillan—an assumption that seems effectually negatived by the absence of any evidence whatever of such a break in the excellent section at Salmon River falls.

Though the Oswego is correlated with the McMillan, and probably began in New York and Pennsylvania about the same time as the McMillan in Ohio, it is not to be understood that the two formations are regarded as strictly conterminous. Such equality might be defended if the New York representative of the Oswego alone were compared with the McMillan. But the much thicker development of the former in Pennsylvania, where a maximum thickness of 700-800 feet is found, coupled with apparent local transition into the overlying Juniata, suggests that Oswego deposition may have continued into the interval between the last of the marine deposits of the McMillan at Cincinnati and the first of the succeeding Richmond invasions. The suggested transition from the Oswego to the Juniata in Pennsylvania is indicated by the intercalation of Juniata-like red beds in the upper 200 feet or so of the Oswego. But as we shall see when we come to the discussion of the physical evidence of the break at the top of the Maysville, this possible transition may be more apparent than real. However this may be, very clear indications of some kind of break are commonly observable in places where either or both of the concerned formations have attained exceptional thicknesses. The point is raised here only to prevent misconception regarding my views as to the relations of the Oswego sandstone to the McMillan formation. It is probably well to add here that, even if actual continuity of deposition from the Oswego on into the Juniata could be established, the fact would not detract from the validity of the conclusion subsequently reached, that the boundary between the Ordovician and the Silurian is to be drawn in America at the base of the Juniata. Systematic stratigraphy is based primarily on data pertaining to marine sedimentation. But the Oswego and Juniata formations are not strictly marine deposits, hence deposition of the former may have continued into, and the latter may have begun before the close of the interval that separated the retreat of one sea from the next, succeeding advance of marine waters.

Though great uniformity of opinion and practice prevailed among geologists regarding the base of the Silurian in New York, considerable difference is noted when we compare results in different parts of the country. But the departures from the New York standard seem in nearly all cases to have been caused by error in identification of beds and not to varying opinions as to where the line should be drawn. All agreed that the lower Medina together with the supposed basal conglomerate—the Oneida—is the first of the Silurian deposits; and all tried to identify corresponding formations wherever stratigraphic work was carried on in and to the east of the Mississippi valley. In Pennsylvania and Maryland where the Medina formations are thicker, but otherwise much the same as in New York, the task was carried out successfully except in that part of the section which was identified with the Oneida. But the Pennsylvania geologists were not responsible for this error. They found a more or less conglomeratic sandstone—the Oswego—beneath the red Medina (Juniata), which, following the prevailing misconception, they very naturally identified as Oneida. Farther south in the Appalachian region the supposed Oneida was known to be absent; and here the first reddish sandstone following the undoubted Ordovician limestone and shale formations was generally accepted as representing the lower Medina. That this reddish sandstone has, as a rule, proved to be of the age of the Pulaski of New York and the Fairview of the Cincinnati section does not mean that a different base for the Silurian was intended, but only that an erroneous identification of the lower Medina had been made.

The identification of the Medina having been generally accomplished solely on the basis of lithologic characters, colour, and absence of fossils, it was quite natural when it came to the typical Richmond of the Cincinnati uplift that these beds, which are filled with fossils and only very sparingly sandy and reddish, would not be recognized as corresponding to the lower Medina of New York and Pennsylvania. Faunally and lithologically they resembled the underlying Ordovician formations, so without paying the least attention to the question of what the fauna of the lower Medina epoch might look like, the Richmond was described as the upper division of the Cincinnati series. That the lower Medina might change its colour from red to greenish-blue, and that it might at the same time become more calcareous and fossiliferous seaward from the old lands that are responsible for its typical characteristics—all of which is now established—was neither suggested nor thought of ten years ago. The conviction that the Richmond is an older group than the lower Medina, and that the latter practically pinches out southwestwardly from western New York and Ontario before crossing the state of Ohio, was too well fixed. The Ohio section of literature, therefore, has nearly always a distinct red Medina formation above the Ordovician, the latter of which is described as including the Richmond. Judging from present knowledge, this Medina is probably only lower Medina and therefore of Richmond age; and the apparent loss in thickness southwestwardly does not affect the formation itself but only the areal distribution of the red colour which, as it seems to have increased with time, caused corresponding diminution in thickness and finally outlap of the red beds away from the contributing land.

Before taking up the discussion of the evidence from which we are to determine which of several likely stratigraphic boundaries is best entitled to the distinction of being recognized as the intersystemic line, I wish to forestall a probable stand of certain geologists who have already gone on record as favouring the systemic severance of the lower Medina from the upper Medina. These authors may seize on my conclusion (see p. 625) that the Lower Llandovery, hence the base of the Silurian in Britain, is probably not older than our Albion (upper Medina), as an unintentional substantiation of their view that the Silurian should begin in America with the Albion. But it is to be said in reply to such a statement that there are two sides to all stratigraphic boundaries: there is a lower side as well as the upper. The base of the formation immediately above the line in Britain corresponds, as I have said, to our Albion. But how about the rocks on the under side—those that make the top of the British Ordovician? These, as is indicated by faunal comparisons, can not be much younger than our Eden. By the same token then, the top of the Ordovician should be drawn in America at the top of the Eden. In that event, what would we do with the intermediate Maysville and Richmond groups? SCHUCHERT has solved the question in a way by proposing a "Cincinnatic system," which is to include the Maysville and the Richmond plus a part of the underlying Eden group and the overlying Ellis Bay formation of the Anticosti section, which I regard as basal upper Medina. But is there room for an intermediate system that would be even approximately comparable in value to the adjoining systems? That I do not think so is clearly stated in my discussion of SCHUCHERT's new system on pages 610 to 615.

Faunal Aspects of the Case.

General remarks.—Foremost among the matters to be remembered is the fact that the evolution of faunas is, on the whole, a continuous process. In our work as practical stratigraphers we are liable to forget this fact. We find a fossil fauna and decide its age at once as Ordovician, or Silurian, or Jurassic, as the case may be. Often we determine it more exactly as Trenton; or it may be that we recognize an even narrower zone. In most instances the determination is correct. Strange as it may seem, the percentage of error is probably less for the minor determinations than where the broader identification and delimitation of systems is concerned. In the former we depend on the definitely proved range of particular species or varieties, in the latter on a much looser aggregate conception.

Accepting organic evolution as a law, and the stratigraphic column as containing an imperfect record of particular stages of the process,[1] it is obvious

[1] In my *Revision of the Paleozoic Systems*, p. 498, the opinion is expressed that "the faunas of the continental seas consist almost entirely of organisms that have periodically and very frequently migrated from their permanent oceanic habitats into these inland seas." For various reasons "the faunas of these inland basins were often exterminated locally. The supply, however, was inexhaustible and ever ready to take advantage of opportunities to replenish the shortage." Evidence is also presented to show that the observed modifications of the fossil marine faunas in the continental basins did not take place in these basins subsequent to their invasion but in the oceanic basins during relatively longer periods preceding their inland migration.

that what we call species and genera must frequently have become extinct during the "intervals of inaccessible record,"[1] that separated the periodic invasions of continental basins by oceanic waters and their faunas. Very often, too, certain species, or even whole faunas, were excluded for one reason or another, from the continental basins whose sedimentary records we, as geologists, are privileged to study. But total extinction, or even complete specific modification, of the fauna of any of the oceanic distributing realms could never have occurred during the interval of nonaccessible deposition separating any two periods. Some inappreciably or but slightly modified descendants, their number often constituting a large percentage of the species of the earlier faunal stage, always remained when the new facies entered into the accessible record. As a rule, too, these survivors are of the vigorous types that, despite the changed environmental conditions, are likely to remain dominant members of the new as they were of the older faunas. Consequently, if it happens that such a transitory stage has not yet been incorporated in our standard of comparison, erroneous identification of the faunally simulating but chronologically quite distinct beds commonly results.

As the fossil record of the faunal change, in passing from one age to another, shows that the change is in no case complete, it is no more than we should expect to find that a large, or at least a considerable proportion, of the species living in one period continued to exist practically unchanged, or in but slightly modified form, into the next. That they did so is convincingly shown by the Helderbergian fauna,—now properly classed as Devonian—which is made up to more than half of species having close genetic affiliations with otherwise typical Silurian types. It is illustrated also by the difficulty experienced by all paleontologists in deciding the question as to where the line should be drawn between the Devonian and Waverlyan; and again by disagreements regarding the true age of beds which some paleontologists claimed, on the basis of general faunal lists, to be Tennesseean or Mississippian, but which others finally proved to be of early Pennsylvanian age. Another good illustration of the persistence of faunal aspect from the period in which it was best displayed into the early part of the next is found in the lower Eocene fauna of the Midway formation. Years ago, I studied the bryozoan fauna of the Midway and decided it to be Cretaceous because of the close alliance of many of the species to Bryozoa of the Rancocas in New Jersey and of typical Cretaceous deposits in France and other European countries. This belief met with the unqualified approval of Dr. C. A. White; but it was wrong nevertheless, all being now agreed that the Midway is Tertiary and not Cretaceous.

As the faunal conception ascribed to any one system or period is but a part of a continuous process of faunal evolution, it is only natural that the

[1] The intervals of inaccessible record are those perhaps often very considerable parts of the total marine sedimentary record that were laid down in the oceanic and other deep troughs or basins during times of continental emergence and hence are now buried beyond reach of possible investigation.

general aspect of the life of a given period is most like that of the periods immediately preceding and succeeding. Obviously, too, other conditions being equal, this intimacy of relation grows proportionately greater as we approach the boundaries from either side. Clearly then, the determination of this collection of fossils as an Ordovician fauna, that as Silurian, and another as Cambrian, is but a more or less arbitrary age assignment of species according to personal or recorded knowledge and belief regarding their vertical or time range.

But relative similarity or dissimilarity of immediately succeeding fossil faunas is not necessarily a true index of the time involved, for similarity in composition may mean only that both invaded the continental basins from the same oceanic basin; and the two may resemble each other very greatly even though a long time interval elapsed between them. On the contrary, two closely succeeding or approximately contemporaneous faunas may be greatly or wholly different when the second happened to invade from another oceanic basin in which an altogether distinct fauna existed at the time. Striking illustrations of this important principle are cited in my recent work. It is particularly applicable in the present discussion.

Applying the foregoing principle, we may readily see that, if our conception of the fauna of a given period is made up chiefly of organisms that invaded from a different oceanic basin than the one which supplied most of the known faunas of the next preceding period, the general aspects of the faunas of the two periods would be different. Moreover, as the characteristic aspect of the second period may set in earlier in certain continental basins than in others, it is easily seen that the recognition of the new period in the deposits of the latter basins would be obscured and probably delayed by the local survival and preponderance of the faunal aspect which prevailed, perhaps in the same basin, during the preceding period. It thus may happen, as it has in the case of formations adjacent to the Ordovician-Silurian boundary in the Ohio and Mississippi valleys, that surviving elements in areas favourably situated for such survivals of the faunal aspect commonly regarded as characteristic of the older period have been given undue weight. The beds in which these surviving faunal expressions are found have been, therefore, wrongly classified as older than contemporaneous deposits in the East and in the far West from which the descendants of the older fauna were excluded by physical barriers. The latter areas, on the contrary, being sooner brought into communication with the north middle Atlantic and the Arctic realms whose life dominated the faunal aspect of the deposits of the succeeding Silurian period in America, it is a perfectly obvious consequence that the first fossiliferous deposits in areas so situated as to oceanic communication, must exhibit a proportionately stronger Silurian expression than could have obtained in those median areas which, at that time, still maintained communication with the Gulf of Mexico. Because of this continued communication with the southern faunal realm the life of the early Silurian seas of the Mississippian, or rather the Ohioan province, maintained much of the expression that had more generally dominated the aspect of the preceding Ordovician faunas in America.

The Richmond faunas of the Cincinnati region remind much more of the preceding Ordovician faunas of the same region than do the Richmond faunas in the Atlantic, the northern, and far western provinces. The faunas in the latter three provinces have much in common and indicate close relations between the northern Atlantic and Arctic seas from which their faunas invaded. The m[illegible] striking peculiarity of the Richmond faunas of the Ohioan province lies in the large number of trepostomatous Bryozoa which they contain. Though Bryozoa occur also in the Anticosti Richmond, and locally in the Richmond deposits of Wyoming and Manitoba, they are chiefly of types that di[illegible] reach the Ohio and Mississippi valleys till near the close of the Richm[illegible] in some instances, and early upper Medina in others. However, th[illegible] bulk of the Bryozoa in the Ohio valley belongs to genera, or to groups of species of certain genera like *Monticulipora*, *Atactoporella*, *Homotrypa*, *Bythopora*, *Batostoma*, and *Heterotrypa*, that are wholly unknown elsewhere in rocks of this epoch. Though specifically distinct, these bryozoa are comparable only to Trenton and Maysville species of the same genera. Indeed, we can not doubt that these Richmond forms are modified descendants of known Ordovician representatives of the genera mentioned. Neither is there any reason to doubt that the Richmond occurrences of these bryozoa invaded the area from the south just as their progenitors must have done.

With these Richmond Trepostomata occur also species of other classes of animals that similarly indicate the southern origin of a large part of the Ohio Richmond fauna. Most of these are pelecypods, gastropods and cephalopods, of genera that had become well established in the Ordovician faunas of the southern states, but are unknown in northern European beds of this age, and in the northern and far western Richmond deposits of North America. A few, however, did reach Anticosti during the Richmond. The more important of these surviving genera are *Byssonychia*, *Modiolodon*, *Ischyrodonta*, *Whitella*, *Cyrt[illegible]ta*, *Orthodesma*, *Cymatonota*, *Psiloconcha*, *Tryblidium*, *Archinacella*, *Bucania*, *Salpingostoma*, *Cyclonema* (typical), *Cyrtocerina*, and *Gomphoceros*.

Despite these conspicuous molluscan and bryozoan reminders of Ordovician faunas, the Richmond faunas of the Cincinnati uplift yet comprise a host of generic and specific types that distinguishes them at once from all preceding faunas. Many of these new generic types continued on into later Silurian ages; others began and seem also to have ended with the Richmond. Among the characteristic species are *Streptelasma rusticum*, *Columnaria vacua*, *Protarea richmondensis*, *Tetradium minus* Nicholson (not Safford), *Beatricea undulata*, *Rhombotrypa quadrata*, *Rhynchotrema capax*, and *R. perlamellosa*—all widely distributed and likely to be found in any North American Richmond locality. The presence of these generally distributed Richmond guide fossils in the Richmond of Ohio and Indiana seems conclusive proof that the beds elsewhere which contain them belong to the same group and epoch. Admitting this correlation, we establish at once that the numerous Ordovician reminders in the Indiana-Ohio Richmond are not indicative of greater age, but only of their continued existence in the southern oceanic realm and in its epicontinental extensions. At the same time it necessitates the assumption that these southern types had not then reached the Arctic centre of dispersal. So far as we know, they never did join either the Ordovician or the Silurian Arctic faunas. In other words, the granting of the faunal correlation establishes my contention that, while all of the various Richmond deposits belong to the same epoch, the basins in which they were laid down differed radically in their oceanic connections.

The Silurian faunas of Britain and northern Europe, likewise most of the Silurian faunas of North America, having invaded the various continental basins from the Arctic and North Atlantic realms, the reason is clearly apparent why the Silurian affinities of the Arctic Richmond faunas of the Rocky mountains and northern Canadian provinces are more prominently displayed than in the Ohio Richmond faunas. In fact these Arctic Richmond faunas, particularly their coralline facies, have been almost invariably identified as Silurian by reputable paleontologists. But it is not to be supposed that these Arctic Richmond faunas are much more distinct from Ordovician faunas than are the southern. They are, of course, quite distinct from the Ordovician life of the southern seas, but when they are compared with their Ordovician predecessors in the Arctic fauna many simulating features are to be noted. The facts in the case are precisely as we should expect them, namely, the Ordovician and early Silurian facies of the Arctic fauna, the same as the corresponding facies of the southern fauna, have much in common. There is no sharp and thorough break between either. In both realms the observed changes in the faunas are but variously spaced stages in a continuous process of modification; and when altogether new types enter the pictures they do so as migrants from some other faunal realm.

The persistence of "Ordovician types" in the Arctic fauna till well into the Silurian period is so clearly displayed in the Anticosti section that BILLINGS and others who studied the beautifully preserved fossils of this island thought it necessary to institute a special "Middle Silurian" epoch in accounting for the mixed faunal assemblages. More recently SAVAGE proposed the term "Alexandrian" for beds in the Mississippi valley in which a similar mixture of Ordovician and Silurian types is observable. In the latter case, however, the Ordovician reminders consist chiefly of derivatives of southern late Ordovician and Richmond species and genera, such as *Cyclocystoides illinoisensis*, *Gaurocrinus splendens*, *Dalmanella* aff. *jugosa*, *Strophomena* aff. *filitexta*, *Zygospira* aff. *recurvirostris*, *Rhynchonella* aff. *increbescens*, *Byssonychia* sp., *Pterinea* aff. *corrugata*, *Psiloconcha* aff. *subrecta*, *Rhytimya* sp., *Lyrodesma*, sp., *Ceratopsis* sp., *Krausella* sp., *Encrinurus* (southern type), *Proetus* aff. *determinatus*, and *Lichas* cf. *breviceps*. But there can be no reasonable doubt that in both cases these "Middle Silurian" rocks are of middle to late Medinan age. Moreover, they are so intimately connected faunally with underlying beds that are unquestionably of Richmond age, that no one who considers all sides of the question will favour drawing the systemic boundary between them. SCHUCHERT and SAVAGE have attempted to do this in Anticosti and southern Illinois, but the former at least admits that the dividing line as drawn by him is an arbitrary one.

As a general proposition we may say that fossil faunas have no absolute time values. An important exception to this rule is made by those small associations in a particular province which mark definite invasions or zones that may be traced from place to place. So far as it is possible to establish contemporaneity of geological events, these usually thin zones are to be counted as absolute datum planes. Correlations based on such occurrences are definite, and in so far as the invasions extend and their zones have been identified, the basis of the correlations is incontrovertible. But when it comes to those broader faunal conceptions by which we presume to correlate the limiting deposits of epochs and periods the world over, the age determinations are much more uncertain. I do not mean to say that accurate correlations in the latter cases are impossible, because I firmly believe that they can, and finally will be made. What I do claim is that they are impossible under the yet prevailing practice of mere "matching" of faunas. Certain species or particular faunal associations may and doubtless do mark unmistakably certain zones in one province, but the same species —probably a little modified—and often very similar associations, may have appeared earlier in another province and later in a third. In other cases it may be that local continuance of oceanic connection enabled a fauna to exist in such places to a later date than is contemplated in our conception of faunal ranges.

Before deciding their ages, we need to analyze the several local faunas very carefully with respect to the life history and derivation—areal as well as genetic—of the species contained in them. We need to learn where the species originated and when and how they or their descendants migrated to other provinces. We need also to learn why ordinary associates in one province happen to be absent in another. To be more specific, why so many "Ordovician" types survived into the Ohio Richmond but are absent in the northern and western Richmond. In short, we must learn to know when an "Ordovician" fauna is really Ordovician and not either Cambrian or Silurian.

As is perhaps well known, I hold to the principle that in marking geological time boundaries, dependence is to be placed on the *introduction* of new fossil types rather than on the *general composition of the fauna*. The new things usually indicate that physical changes have taken place in the meantime; and the importance of these changes is commonly in proportion to the degree in which the old fauna has been changed by the addition of new elements. But, like all the other principles affecting stratigraphic correlation, especially where deposits of distinct provinces are concerned, this also must be applied with extreme caution. The first appearance of one or several associated species may be an unfailing and invariable criterion throughout a given province, but in another province the same species may have a less exact and perhaps quite different significance. Thus, as I have stated in part on a preceding page, in the Appalachian and Ohioan provinces *Atrypa marginalis* is confined to a definite and rather thin zone in the upper Medina which seems to be of the same age, whether found in Missouri, Ohio, or east Tennessee. In Anticosti this fossil is said to have a range of 230 feet, most, if not all, of which seems to be older than the *Atrypa marginalis* zone in the Appalachian valley. In Britain this species occurs in the lower Llandovery and is also reported as being found in the Ordovician. *Anoplotheca hemispherica* is a common and widely distributed fossil in the Clinton of the Appalachian region but is unknown there beneath the Clinton. In the Anticosti section, according to SCHUCHERT and TWENHOFEL, this shell begins in the Gun River formation and ranges upward through 650 feet of beds all of which I believe to be older than the Clinton. Similar differences in age of occurrence in the interior American, the Anticosti, and the British provinces are indicated by *Atrypa reticularis*, *Bilobites bilobus*, and *Pentamerus oblongus*. Each of these five brachiopods has a definite correlation value in the interior American basins that differs in a greater or less degree from the age value of its range in the Anticosti and British sections. Obviously, therefore, their first appearance in the north Atlantic provinces has not the same significance as in the interior American provinces.

In America the presence of a meristelloid or a spiriferoid shell, or of an *Atrypa* in a fossil fauna is ordinarily regarded as unequivocally indicative of post-Ordovician ages. The same is to be said of certain corals like *Heliolites*, *Plasmopora*, and *Favosites*.[1] So far as we know this belief is fully justified by the facts. But these shells and corals seem to have originated in northern waters, so that it is quite proper to find that their appearance in the southern faunal realm was delayed to later Silurian ages. Though some of them crossed the Atlantic to Anticosti before the middle of the second (Albion) stage of the Medinan, some physical barrier prevented their migration into the southern realm until near the close of the Medinan and, in most instances, to the middle and late Clinton invasions. Some of these same corals and shells, notably *Favosites asper* and *Atrypa marginalis*, evidently lived in the Arctic realm already in the Richmond, being found in faunas of that age that must have invaded the continent from that sea as far south as New Mexico.

While these things originated and lived in the northern seas and their dependencies, other organisms lived in and were similarly confined to the southern seas. Hundreds of species are found in the Richmond deposits of the Cincinnati uplift that are wholly unknown in the deposits of Europe and North America, which received the organisms entombed in them from the northern seas. Among these southern Richmond fossils are many peculiar types, some of which are to be viewed as the introductory stages of families that later on became very important. Mentioning only the most striking forms, the list would comprise *Fenestella*, the first of its family; *Lepadocystites*, the first of the *Callocystidæ*. *Compsocrinus* and *Xenocrinus*, the first representatives of the *Batocriniidæ*, and *Meekospira*, the oldest of the *Eulimidæ*. Excepting *Fenestella*, none of the descendants of these southern

[1] If we may rely on published lists of British fossils, all of these genera, besides others that are not seen in America beneath the upper Medina or Clinton (see p. 619), appeared in Britain during the latter part of the Ordovician.

Richmond types reached Britain and the Baltic region before the Wenlock stage of the Silurian. Their claims to be viewed as Silurian genera, therefore, are certainly as well founded, if not better, than those of *Heliolites, Plasmopora, Favosites, Spirifer, Meristellidæ, Atrypa*, and other types which were everywhere established in the seas of the northern hemisphere before the Wenlock stage.

Late Ordovician and early Silurian faunal breaks.—There are four faunal breaks in the late Ordovician and early Silurian rocks of America that should be considered in deciding where the dividing line between these two systems should be located. Beginning below, these breaks occur (1) between the Trenton and the Eden, (2) the Eden and the Maysville, (3) the Maysville and the Richmond, and (4) the Richmond and the Albion. At the outset it should be said that these faunal breaks derive their importance chiefly from the fact that they coincide with boundaries between groups of formations which are distinguished from each other mainly because of physical distinctions. Namely, each group is set off from the one next above and beneath by some difference in average lithologic composition. Moreover, the boundaries between them are more or less sharply defined; and the contacts as a rule present clear evidence of interrupted sedimentation and change in size and shape of seas. The faunal break, therefore, corresponds in each case to an important physical break. It should be mentioned further, that other, no less well marked faunal breaks occur between the confines of each of the groups. The importance of these intermediate breaks is thought to be less for no other reason than that the accompanying physical breaks are less widely and less definitely recognizable. Locally, however,—and in one or two instances over very wide areas—the physical break marking these minor formational boundaries is quite as conspicuous as the faunal break. This is particularly true of the Fairview-McMillan boundary in the midst of the Maysville group.

Although the Trenton and Eden faunas are in many respects similar, it is yet a fact that only a small percentage of their faunas are common to the two. Indeed strange as it may seem, if we compare the Trenton fauna as a whole with later faunas the greatest resemblance is not with the Eden fauna, but with that of the Maysville group. Great variability is notable also in the composition of faunas adjacent to the boundary in different seas. This is due chiefly to restriction of seas and consequently to absence of latest Trenton beds in many places and to absence of the lower members of the Eden because of overlap. Very decided contrasts in Trenton faunas are occasioned by differences in oceanic connections, as when the faunas invaded from the north instead of from the south. But it is unnecessary to discuss these here because they have no immediate bearing on the problem before us.

When the typical Utica, with its Atlantic fauna, rests on the Trenton limestone, as it does between central New York and Cincinnati, a decided faunal break is immediately notable. But this break is less marked in eastern New York and in the eastern or Martinsburg shale outcrops of Pennsylvania and West Virginia, where the Trenton is similarly represented by shale and likewise carries Atlantic faunas. Avoiding details, it may be said at once that the Trenton-Eden boundary, though usually recognizable by a well marked faunal break, is yet not of the taxonomic grade desirable in a systematic boundary. On the other hand, it serves very well as the dividing line between terminal groups of two series—the Mohawkian and Cincinnatian. Besides, there can be no reasonable doubt that the Ordovician of Britain includes beds corresponding to our Eden.

SCHUCHERT drew the top of the Ordovician at the top of the Utica but, as I have said in discussing his "Cincinnatic system" (pp. 610 615), this boundary is a purely paleontological line that is only seldom determinable in the field. The proposal is, therefore, rejected as impracticable. Besides, the natural relations of the Utica, whether viewed from the faunal or the physical side, are with the Eden rather than the Trenton.

The Eden-Maysville faunal break is generally recognizable wherever deposits of both groups are present. As a rule, however, the Mount Hope member of the Maysville suggests transition—a gradual dropping out of upper Eden species in favour of characteristic Maysville species. By the time we reach the second or Fairmount member of the Fairview formation little remains of the older faunas. The small Eden remnant, at least is scarcely noticeable in the usual Fairmount fauna at Cincinnati. It is also very weak in the nearly corresponding Pulaski fauna in New York, and no less so in that of the equivalent beds of the Fairview in the middle and southern Appalachian region. A greater percentage of the Fairview fauna consists of obvious, though in most cases specifically modified, descendants of Trenton species which are entirely unrepresented in the intervening Eden formations. However, despite these apparent hold-over and recurrent species, the Fairview fauna comprises such a host of characteristic fossils that there is rarely cause for even a moment's hesitation in identifying it. Actual error in determination might occur only in the southern Appalachian region and in central Tennessee where a similar fauna is found in the Catheys, a late Trenton formation, that is often found directly under the Fairview. In such cases, of course, the contact between these simulating formations represents an important hiatus which is occupied in northeastern Tennessee by as much as 1,500 feet of calcareous shale.

In the Cincinnati section the Fairview is succeeded by the McMillan formation. The latter is even more highly fossiliferous than the former; and very few of the species are common to the two formations. Indeed, out of approximately 250 species found in the McMillan, not over 15, or possibly 20, are indistinguishable from Fairview species. Besides, these 15 to 20 hold-overs consist mostly of long-ranging types, some of them—if we are not inclined to nicety in systematic paleontology—beginning low in the Trenton and continuing on into the Medina and Clinton. Evidently the faunal break between the Fairview and the McMillan is more than usually complete. As we shall see presently, it followed important displacements of the strand-line, a fact that must add considerably to its significance.

The Maysville-Richmond faunal break is sufficiently discussed in commenting on the proposed "Cincinnatic system" of Schuchert. Certain other aspects of the break are discussed a few pages back where they are used to illustrate the principle of synchronous faunal differences due to varying oceanic connections. Of the faunal breaks concerned in the selection of a satisfactory boundary between the Ordovician and Silurian systems, the one separating the Richmond from the preceding Maysville is not only the strongest, but it also divides the faunas according to their greatest affinities. The Maysville fauna is too intimately related to the preceding Eden and Mohawkian faunas, in other words it is yet so throughly Ordovician in its composition that, despite its apparent absence in the Ordovician of Britain, we are obliged, on the ground of natural relations, to add it to the top of the lower system. The Richmond fauna, on the other hand, is so intimately connected with succeeding faunas that are unquestionably of Silurian age that there is seemingly no choice but to classify it with the later formations in the upper system. The propriety of dividing the American beds which seem to represent intersystemic intervals not represented by deposits in the British section by adding one part to the top of the Ordovician and the remaining part to the base of the Silurian, seems assured when we find that the systemic boundary as indicated by the fossils corresponds accurately with the line as drawn on purely physical grounds.

Physical Aspects of the Case.

General statement.—The aspects of the problem which remain to be discussed are those strictly physical phenomena that indicate vertical and horizontal movements of or within the shell of the lithosphere and consequent shiftings of the strandline. The phenomena consist chiefly of (1) changes in the character of deposits, sometimes indicating elevation and enlargement of land areas, at other times submergence and, therefore, expansion of water areas, and finally, such less satisfactorily determinable conditions as climatic changes, the relief of the land areas, and the relative duration of the periods of emergence; (2) sharp breaks in the sedimentary sequence, with or without marked discordance of bedding, indicating interruption of deposition—usually because of emergence—and consequent erosion of the surface that had been subjected to tidal or other marine currents or to subaerial conditions; (3) variation in areal extent and in relative thickness of corresponding beds, that is, (*a*) thinning or thickening of formations in any direction by loss from or by addition to the base, indicating advancing seas and consequent overlap of deposits, or (*b*) by absence of beds at the top, indicating retreat of seas and restriction of areas of deposit or removal of beds by erosion prior to the next succeeding submergence; and (4) variation in general distribution of formations, indicating decided changes in geographic pattern of land and water areas. The significance of these strictly diastrophic physical phenomena is as a rule readily apparent. Besides, I have recently discussed the criteria and principles of stratigraphic correlation by diastrophic movements at considerable length.[1] It seems, therefore, unnecessary to introduce this section with a generalized dissertation on the use of physical criteria in stratigraphic correlation and taxonomy. Moreover, such a discussion, if it should be of real service, would take up more space and time than is now available.

Late Ordovician and early Silurian displacements of the strandline.— In seeking to determine which of several well marked boundaries is the most natural and at the same time the most practical dividing line between the Ordovician and Silurian systems in America, our choice is limited to those following the Trenton and preceding the Clinton. This limitation is enforced by the certainty that the whole of the Trenton at least falls beneath the top boundary of the Ordovician as represented and defined in Britain, while it is equally certain that the base of the Clinton is younger than the base of the Lower Llandovery, with which the Silurian, according to LAPWORTH'S classification of British Paleozoic deposits, begins.

The important movements, which attained their culmination at the close of Ordovician marine sedimentation in the accessible epicontinental basins of America, began early in the Mohawkian epoch. Increased elevation of old and long-weathered lands along the Atlantic border at the beginning of this epoch is indicated by the red sediments which are found in the easternmost development of Lowville rocks in the Appalachian valley of Tennessee. These reddish and argillaceous Lowville deposits constitute the typical Bays sandstone of Bays mountain. However, while the elevation of Atlantic border lands was going on, subsidence prevailed in the interior areas. The Lowville formation consequently overlapped the preceding Ordovician deposits in New York, Ontario, Wisconsin, and Missouri, the farthest edge in some places being in contact with Pre-Cambrian rocks. In the Appalachian valley also, beds of this age locally extend farther eastward than usual for formations of the Ohioan province. The extent of the Lowville sea is shown in the first of the paleogeographic maps.

The Lowville stage of general subsidence in the southeastern quarter of North America was followed by another stage, characterized by abundant but gentle surface warping and oscillating seas which, on the whole, were less extensive than the Lowville. This is represented by the numerous thin and areally limited upper Black River formations.

The next important stage of these movements set in with the beginning of the Trenton group. In the Appalachian valley the deposits of this group do not extend so far east as those of the Lowville, being here confined to the middle and western bands. The outcrops which represent the eastern extent of the Trenton sea are again red, thus suggesting elevation of the Atlantic border lands similar to that inferred in the preceding Lowville age. These second, early Trenton, red deposits are included in the Moccasin limestone of the western ranges of the valley. It should be said, however, that most of the deposits referred to the Moccasin in the middle ranges in northeastern Tennessee are of Lowville and probably later Black River ages. To the

[1] *Revision of the Paleozoic Systems*, Bull. Geol. Soc. America, Vol. XXII, 1911, pp. 394-574

west of the Appalachian valley the early Trenton sea spread widely, though there is ample evidence to show that several wholly distinct inland seas contributed to the present aggregate extent of Trenton deposits in North America.[1] These distinct components of the Trenton indicate broad warping of the great interior area and differential tilting of the continent, hence an advanced stage in the series of movements which culminated at the close of the Ordovician and finally produced the very different geographic pattern that prevailed through the greater part of the Silurian period.

During the later ages of the Trenton small and oscillating seas again prevailed. Apparently they were confined entirely to the Allegheny geosyncline and the northern part of the Appalachian valley, spreading now and then into the western half of the southern Appalachian Valley region, and more commonly to the shallow basins immediately to the west of the Cincinnati axis. But late Trenton deposits are wholly wanting in the Mississippi valley to the north of Ohio river and, so far as known, throughout the middle, northern and western parts of the continent.

Conditions similar in many respects to those characterizing the late Trenton continued into and prevailed through the Eden stage. The main difference lies in this, that the sediments in the latter stage consisted chiefly or entirely of fine muds and sands from which it is inferred that the contributing lands to the southeast and northwest sustained somewhat greater elevation. This increased elevation seems, however, to have affected only the southern part of the Atlantic border land, since nearly all of the Trenton deposits in the valley region between Canada and Virginia likewise consist of shale and sandstone. In this region, therefore, there is no lithologic break between the Trenton and Eden. Another difference is seen in the fact that, whereas the late Trenton is well developed on both the Cincinnati and Nashville domes, the Eden fails entirely to outcrop on the latter dome and is at least locally wanting also on the southern flank of the former. Evidently the southern half of the Cincinnati axis was raised above sea level at the close of the Trenton.[2]

As we see from this brief account, the diastrophic movements in America at the close of the Trenton were relatively gentle and merely an accentuation of a series of movements begun during earlier stages of the Mohawkian epoch. Besides, over a large part of the outcrop of Trenton and Eden deposits in the Appalachian region it is impracticable to draw even a formational boundary between the two. We conclude, therefore, that the Trenton-Eden contact offers no satisfactory physical basis for a systematic boundary. As the organic evidence led to the same conclusion, we are fully justified in passing on to the next important break.

As noted on preceding pages of this paper, SCHUCHERT proposed limiting the Ordovician above at the top of the Utica shale. In my opinion there is little ground for this procedure even on the basis of fossil distinctions, and

[1] See *Revision of the Paleozoic Systems*, pp. 367-370.

[2] A fuller statement of the oscillations of the domes of the Cincinnati axis is given in my *Revision of the Paleozoic Systems*, pp. 416-419.

very little indeed from the standpoint of diastrophism. Where the Utica is followed by later Eden deposits, it is always difficult to draw a sharp line between them. In fact, there seems to be no such line in areas like the middle and northern Appalachian Valley regions, where the Eden is greatly developed. Even in central New York the typical Utica seems to pass gradually into the overlying Frankfort shale. In the vicinity of Cincinnati some movements occurred between the two, so that here careful study of outcrops enables us to distinguish a definite line of contact between the Fulton (Utica) and Economy members of the Eden.

The Eden-Maysville break.—The contact between the Maysville group and the Eden is nearly always more or less sharply indicated by a change from shale or argillaceous sandstone to limestone or calcareous sandstone. A notable exception to this rule is seen in central Pennsylvania, where shale deposition began at various times in the Trenton or with the Utica and continued almost to the close of the lower half of the Maysville. This continuity of shale deposition is best displayed in the mountain ranges between Lewiston and Milesburg, especially Jacks and Bald Eagle mountains, in which the interval between the top of the Trenton limestone and the base of the Oswego sandstone consists wholly or chiefly of shale. The upper part of this great mass of shale, to which I have applied the name "Reedsville shale," because it seems to constitute an indivisible formational unit, is usually arenaceous and generally marked near the top by characteristic fossils of the upper *Orthorhynchula linneyi* zone. In the Appalachian valleys to the south and in central Tennessee and Kentucky this zone belongs at or near the top of the Fairview division of the Maysville.

Where the Reedsville shale facies obtains, the usual break between the Eden and Maysville is indistinguishable. However, in New York and in the vicinity of Cincinnati the break between the two is often clearly defined. Usually it is marked by evidence of intervening retreat and subsequent return of marine waters. Now and then erosional unconformity is suggested at the contact, and in many cases the suggestion is confirmed by overlap phenomena. That diastrophic movements did occur at this time, movements that occasioned subsidence and submergence of considerable areas that had been above sea level during the preceding stage, is established by the general overlap of early Maysville deposits in south-central Kentucky, throughout middle Tennessee, and as a rule in the southern Appalachian Valley region. In these areas the Maysville rests either commonly or always on Trenton rocks, the Eden being wholly absent or only very locally present.

Further evidence of earth movements following the close of the Eden stage is found in southwestern Virginia and northeastern Tennessee. In the middle and western valley ranges in this area the Eden attains unusually great thickness. Succeeding it we find another red formation, the third of the series of red Ordovician deposits of which the typical Bays sandstone—of early Black River age—is the first, and the upper Moccasin limestone or shale—of early Trenton age—is the second. The third red formation has been mapped as "Bays sandstone," but is really a much younger formation.

In fact the fossils contained in it, and its stratigraphic position with respect to the underlying Eden and Trenton formations, prove it to be the equivalent of the Fairview limestone of the Cincinnati section. Whether it represents the whole of the Fairview or only its upper part has not been decided. That the latter view is at least locally true as, for instance, in Walker Mountain, Virginia, seems probable. There is also some reason to believe that the upper layers of this Appalachian Maysville formation are younger than the top of the Fairview at Cincinnati and that they really belong in the hiatus between the Fairview and the McMillan in the Ohio section. However this may be there is no paleontologic evidence, so far as known to me, warranting correlation of the upper part with the McMillan; and absolutely none for claiming, as has just been done by Professor A. W. Grabau, a Juniata-Richmond age for any of the several wholly distinct beds heretofore referred to in literature under the name "Bays" sandstone.

In discussing the faunal breaks a few pages back I mentioned that the strong life-break between the Fairview and the McMillan ages of the Maysville followed important displacements of the strandline. South of Pennsylvania Maysville deposition ceased in the Appalachian valley with the close of the Fairview. It terminated at about this time also in middle Tennessee. No sediments which are older than Richmond and which might correspond to the McMillan are to be found in either area. So far, fossiliferous beds of this age have been found chiefly on the Cincinnati dome, on which they diminish rapidly to the southward. Elsewhere in North America much smaller faunas of this age have been found only in central New York and southwestern Quebec. Central and western New York and central Pennsylvania, however, contain the Oswego sandstone. This sandstone occupies the same position with respect to the Pulaski and the Queenston, which include the only possible New York equivalents, respectively, of the Fairview formation and the Richmond group in the Ohio section. The McMillan is a highly fossiliferous formation of calcareous shale and thin limestones, the Oswego, on the contrary, a sandstone, often conglomeratic and, except in its basal part, wholly devoid of fossils. The principal facts that are believed to establish the correlation of the McMillan and Oswego formations are briefly discussed on page 627.

Whether actually contemporaneous or not, the restriction of the area of Maysville deposition following the close of the Fairview and Pulaski, likewise the arenaceous and locally conglomeratic composition and the not unlikely land origin of the Oswego, proves that diastrophic agencies were relatively active at this time. Besides, if we compare the inferred movements from the beginning of the Mohawkian on to the close of the Maysville, it is clearly apparent that they form a progressive series of diastrophic events. The eastern border of the successive deposits of red material, which must have been laid down adjacent to the shore, moved farther and farther inland. The first of the red formations is confined to the Athens and Knoxville troughs,[1]

[1] For description of the southern Appalachian Paleozoic troughs see *Revision of the Paleozoic Systems*; also Ulrich and Schuchert's *Paleozoic Seas and Barriers in eastern North America*, Bull. New York State Mus. No. 52, 1902.

the second to the Knoxville, Pearisburg, and Clinton troughs, the third occurs in the same troughs as the second but is best developed in the Pearisburg and Clinton troughs. To the northwest of the Appalachian valley the successive seas advanced and retreated many times, but, speaking in general and broadly, each advance fell short of the preceding high stage, and the last or McMillan stage was much the smallest of them all. When this closed the whole continent emerged; and the next submergence began a new and very different series of marine oscillations. The varying results of these successive diastrophic movements, in so far as their effect on the strandline of the North American continental seas has been determined, are somewhat crudely illustrated on the accompanying paleogeographic maps.

The Maysville-Richmond break.—We have seen how the McMillan stage of the Maysville sea was confined to a small part of the Ohioan province. I have also said that, when the last of the McMillan deposits had been laid down, the whole continent was elevated above sea level. The small extent of the McMillan sea is inferred from the total absence, so far as known, of deposits of this age except in the three areas mentioned in the second preceding paragraph. Possibly they extended originally into areas where they are now absent. But this suggestion implies a corresponding amount of pre-Richmond erosion, an amount so much greater than is indicated by the average character of the succeeding Richmond deposits that it must be rejected. Besides, in the area in which the deposits of Richmond age are particularly clastic in origin and thicker than usual, that is in Pennsylvania and New York where the Juniata and Queenston shales and sandstones are so well developed, they are underlain by the Oswego sandstone. And the Oswego sandstone, we have seen, can not be older than the McMillan. Obviously then, the detrital material of the Juniata-Queenston must have been derived, mainly if not entirely, from other areas than those which had previously received deposits of McMillan age. Finally, it is to be noted that everywhere the base of the underlying formation—whether of Black River or latest Maysville age—almost invariably suggests mere subaerial surface decomposition. No indication of high relief, with steep slopes and consequent active erosion, has so far been observed. The nearest approach to such conditions is seen in the bluff on Sequatchie river a sketch of which, taken from photographs, is reproduced in Fig. 1. As a general proposition, I contend that erosion agencies contributed in only a very small degree to the surficial deformation of negative areas of early and middle Paleozoic lands. Numerous data supporting this view are mentioned in a discussion of the subject in my *Revision of the Paleozoic Systems* (see especially pp. 304–311).

Although the amount of erosion was almost negligible in the negative areas that commonly received marine deposits during the Paleozoic, it seems nevertheless a fact that the interval beginning with the close of the Maysville and extending into the Medinan and early Niagaran epochs was marked by land elevation and consequent denudation of more than ordinary importance. Evidence of this is seen in the great masses of clastic material which accumulated at times during this interval in the Appalachian Valley region of Pennsylvania and adjoining states. These deposits reach an aggregate thickness of over 5,000 feet, divided between the Juniata, Tuscarora, and Clinton formations. Such a volume of detrital matter necessarily implies considerable elevation of the lands from which it was removed, and as the mass diminishes in thickness to the north, west and south from central Pennsylvania, we are obliged to assume that its source lay mostly to the east and southeast of the same point.

Since the first 1,000 feet or more of these detrital formations—the Juniata-Queenston—consists very largely of reddish sediments, we infer (1) that a large area of old and well-oxidized land was included in the general uplift which followed the Maysville, and that this land was elevated sufficiently to make it contribute liberally to the composition of the next succeeding Juniata formation; and (2) that either this old land had con-

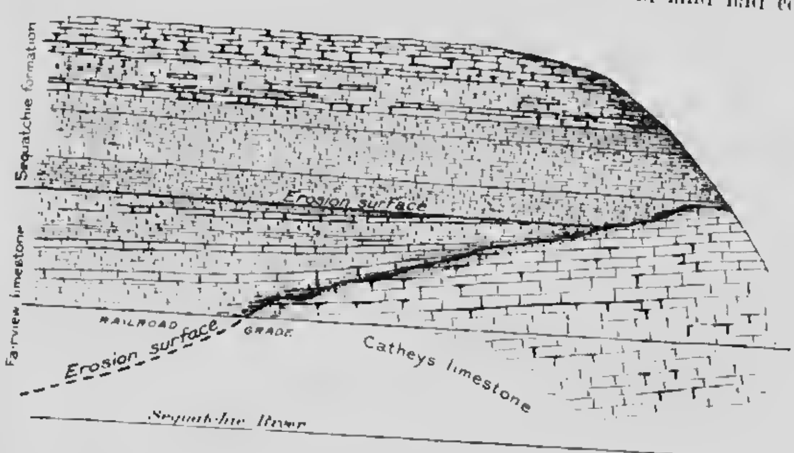


FIG. 1.

tributed very sparingly to the preceding late Ordovician seas of the Appalachian valley, or that the interval of general emergence between the Oswego and the Juniata was of sufficient duration to accomplish deep weathering of the concerned land. Our present purpose of showing the diastrophic importance of the Oswego-Juniata or McMillan-Richmond interval is not materially affected by a choice between these alternative possibilities. Both may be partly true, but judging from the sequence of red sediments in southwestern Virginia and northeastern Tennessee, the latter of the two seems the more important cause. Namely, in the contiguous areas mentioned the Fairview, which here immediately underlies the Richmond, is also red. Here, then, oxidation of the contributing land must have been revived and accomplished to considerable depth before the close of the emergent interval which followed the Fairview and preceded the Richmond.

Speaking of the sequence of red deposits in the Virginia-Tennessee area, I am reminded of the fact that the Sequatchie formation, the representative of the Richmond in the southern Appalachian region, is the last of the series. Comparing the location of its eastern border with that of the older members of the series—the Fairview, late Moccasin, and the typical Bays—we observe that it follows the rule by lying farther to the west than its predecessors in the series. Namely, the eastern border of the Sequatchie usually is confined to the Clinton trough. It is not only an interesting but also a highly significant fact that the upper Medina (Rockwood) of Tennessee is similarly confined to the Clinton and more western troughs. The unfossiliferous Clinch sandstone, on the contrary, has its best development in the western half of the Knoxville trough. The progressively western movement of the eastern margin of these red formations is probably in obedience to the hypothetical law of "inland migration of belt of active folding," suggested and discussed in the *Revision of the Paleozoic Systems*, pages 434-446.

That the highest part of the Atlantic borderland (Appalachia), from Pre-Cambrian time on to the close of the Maysville epoch, was generally in the south, perhaps particularly in North Carolina, is clearly indicated by the great thickness of the pre-Silurian deposits in east Tennessee, Georgia, and Alabama. Most of these deposits are strictly of detrital origin; and their aggregate volume (approximately 25,000 feet) is far in excess of the total attained by the pre-Silurian deposits in Pennsylvania. Greater altitude for southern Appalachia is also indicated by the more frequent occurrence of red formations in the southern Eopaleozoic section. In Pennsylvania we have only one during this era—the middle Cambrian Waynesboro formation.[1] In Tennessee, however, there are at least five, one in the middle Cambrian and four (Tellico, Bays, upper Moccasin and "Fairview") in the Ordovician. Comparing the distribution of the four Ordovician red formations it appears that the southern terminus of each is farther north than the one immediately preceding. In view of the last fact, it is thought probable that the point of greatest altitude advanced northward continuously or periodically during the Ordovician. At the close of the Maysville it must have passed into southern Virginia.

With the beginning of the Medinan the balance had been turned. From then on to the close of the Devonian the highest lands of Appalachia were in its northern part—probably in southeastern Pennsylvania.[2] Beginning with the Juniata and continuing with the Tuscarora and Clinch, then the Clinton, the Cayugan, the Helderbergian, and finally the Neodevonian formations, the area containing the greatest thickness of the several formations lies somewhere between northern Pennsylvania and southwestern Virginia. The Juniata attains its greatest development in central Pennsylvania and thins southwestwardly. Nearing the border of Tennessee it seems to pass

[1] Thin bands of red sediment locally present in the Oswego are not taken in account, coming, as they do, at the close of the era.

[2] The expressions, "highest lands" and "greatest altitude" should perhaps be modified, because they refer to the areas which supplied the greatest amount of erosion products; and these, as is readily conceivable, were not necessarily the highest parts of the land.

into the more calcareous Sequatchie formation, in which facies the deposits of this age extend into northeastern Alabama. The Tuscarora likewise attains its best development in Pennsylvania. Following the strike of the Appalachian valley this formation apparently passes laterally into the Clinch sandstone and finally pinches out, or possibly merges into the Rockwood, in east Tennessee. The Clinton is very thick in central Pennsylvania, somewhat thinner in Maryland, but swells again to its maximum thickness in west-central Virginia. From here the northern Appalachian Clinton loses again until it dies out completely in northeastern Tennessee. In general the facts as to the distribution and areas of greatest thickness of the Cayugan, Helderbergian, and Neodevonian are much the same as for the Tuscarora and the Clinton.

Confining our comparisons more particularly to the Ordovician and Silurian formations in the Appalachian region, the differences in distribution which assist in distinguishing the two systems stand out prominently. Thus, while more Ordovician formations are represented and most of them attain their greatest known thickness in Tennessee, and while some of these formations are wholly absent and most of them thinner in Virginia, Maryland, and Pennsylvania, the opposite is true of the Silurian formations. Only one of the Silurian groups, namely, the upper Medina, reaches as great a thickness in Tennessee as in Pennsylvania; and this one is quite different in all other respects from its northern representative. As to the Clinton and the Cayugan, both of which are strongly developed in the north, neither is present in east Tennessee south of Claiborne county. In view of these facts it is positively assured that important changes affecting the geography and topography of the Appalachian valley and areas adjacent thereto, culminated in the interval between the Maysville and Richmond epochs.

Extending our comparisons to the relatively flat interior areas of the continent, the first difference that strikes one is that, whereas all of the Ordovician formations of southeastern North America save those which invaded from the north attained their greatest development in the Appalachian Valley region, the most important members of the middle Silurian series, that is, the upper Niagaran formations, are not present there at all. These are confined to the interior areas. Even the Medinan, the Clinton, and the Cayugan formations do not extend so far east in the valley as the majority of the Ordovician formations. In fact the Silurian formations are almost entirely confined in the valley region to the western ranges.

But, as regards distribution, the greatest difference is that which sets in with the Richmond. As will be recalled, the preceding McMillan stage of the Maysville sea was but a small remnant of the prevailing Ordovician sea. Following it, the epicontinental seas seem to have been entirely withdrawn. However, with the first return of the waters the new sea was immediately much larger. The Arnheim, which is the first of the Richmond formations, is known not only in the vicinity of Cincinnati, but also in west-middle and southeastern Tennessee; and the closely allied Waynesville, which succeeds the Arnheim in Ohio, extends this distribution to Ontario and Quebec. Whether these early Richmond divisions are represented also in the supposedly nonmarine Juniata of Pennsylvania and the Queenston of New York can not be decided at present.

In west Tennessee the Arnheim is succeeded by the Fernvale formation. The Fernvale contains a large and very characteristic fauna by which it may be recognized at once. Although a thin zone—seldom exceeding 25 feet in thickness—the Fernvale seems to be very widely distributed. It does not occur in either the Cincinnati or the Appalachian regions, but is well developed in northern Illinois, southeastern Missouri, northern Arkansas, and south-central Oklahoma. There is some reason to believe that the same zone is represented on the east side of the Rocky mountains in Colorado and also in western Texas and New Mexico, but the most diagnostic of the Fernvale fossils—the bryozoa—are absent in these western localities; and we can not yet say whether their absence is due to failure of transporting currents or to difference in age of deposits. Whether the latter occurrences are strictly correlatable with the Fernvale of Tennessee or not, enough is certainly established regarding the geographic distribution of this zone to show that the early Richmond submergence extended over great areas that had been above sea level through the whole of the preceding Cincinnatian epoch and all or at least the greater part of the Mohawkian.

Other Richmond deposits, most of them doubtless of later Richmond ages, but some of them perhaps quite as old as the Fernvale, have been identified in western Texas, New Mexico, Nevada, Utah, Idaho, Wyoming and Manitoba, and in other areas to the north as far as Seward Peninsula, Alaska, and Baffinland. It seems highly improbable that the full extent of this extraordinary distribution of Richmond deposits was in effect at any particular time. Nevertheless, it is as certain as stratigraphic identification can be, that by far the greater part of the broad area indicated by the named localities was actually covered at certain times by a continuous epicontinental sea that invaded from the north.

In many of these areas, particularly those between New Mexico on the south and Alaska on the north, the Richmond beds are succeeded by later Silurian deposits. Whether any of these are really younger than late Medina can not be decided at this time. Still, it is to be said that the frequent presence of *Pentamerus* suggests submergence as late at least as early Niagaran. Whether Niagaran or not, they are certainly Silurian. This frequent association of Richmond and later Silurian deposits in western and northern North America, therefore, helps materially in proving the claim —primarily based on conditions found in southeastern America—that the distribution of the Richmond in North America conforms essentially with that of the Silurian and not at all with that of the middle and late Ordovician formations.

Besides the above outlined broader diastrophic movements which caused such great changes in the general distribution of the late Ordovician and early Silurian seas, considerable local folding and warping of land areas occurred at or soon after the close of the Maysville. These warpings are particularly notable on the flanks of certain old structural domes like the Ozark uplift and the Nashville dome. In middle Tennessee, for instance, the Ordovician formations up to the top of the Leiper, which corresponds essentially to the Fairview division of the Maysville, form continuous sheets over the whole dome or around one of its sides. With the advent of the Richmond, however, this relatively equable distribution was changed. Warping of the dome had formed shallow hollows which, when the Richmond submergences set in here, lodged small and narrow embayments. The Fernvale, so far as exposed in middle Tennessee, is almost entirely confined to these embayments. When Niagaran time came, a few new embayments may have been developed but for the most part the old inlets were rejuvenated and used again. The Fernvale and St. Clair limestones extended northward in similar embayments of the southern shore of Ozarkia in Missouri and northern Arkansas.

Post-Richmond breaks.—At the close of the Richmond, meaning by that the time when the last of the deposits of this group had been laid down in Indiana, extensive sea-withdrawal occurred. We see this clearly enough in Ohio, Indiana and Kentucky, where a considerable hiatus separates the top of the Richmond from the next overlying formation. In these states the first deposit following the Richmond belongs to the Brassfield or "Ohio Clinton" limestone which doubtless corresponds to the last of the upper Medina beds. Compared with the section in southeastern Tennessee, the post-Richmond hiatus in Ohio represents the White-oak sandstone (400 feet thick) plus a part or all of the smaller hiatus which separates this sandstone from the underlying Sequatchie formation, which is the southern Appalachian marine representative of the Queenston of New York, the Juniata of Pennsylvania and the Richmond of Indiana and Ohio. There is a hiatus at the top of the Richmond also in the Mississippi valley. Though usually of greater value the hiatus is locally cut down in this valley to smaller dimensions than in Ohio. This occurs in southern Illinois and adjoining parts of Missouri where the Richmond is followed by the Girardeau limestone and the Edgewood formation, both of which fall into the lower half of the upper Medina and are succeeded by still younger beds of the same group. It also occurs in northern Illinois where, as at Savannah, deposits approximately of the age of the Edgewood are locally intercalated between the top of the Maquoketa shale and the base of the Niagaran dolomites. In Oklahoma, providing the top of the Sylvan shale is not older than the top of the Richmond in Indiana, the same hiatus has about the same value as in Ohio. In both places the Brassfield *Rhinopora verrucosa* zone is the first to succeed the Richmond. In New York and Pennsylvania also, a break between the lower and upper Medina is commonly recognizable.

Evidently there can be no doubt regarding the actuality of the physical break between the Richmond and the Albion groups of the Medinan series. But it is not of the kind that marks stratigraphic boundaries separating distinct systems and much less, eras. It is rather like those intrasystemic breaks which separate groups and important formations. This is shown by the fact that the general distribution of the Albion formations is on the same plan, only not so extensive, as that of the Richmond formations. Both are simulating parts of a dispensation that is radically different from the preceding Ordovician plan. In the former the Albion differs from the Richmond just about as the Maysville differs from the Eden, or the Lowville from the upper Black River, or the McMillan from the Fairview in the Ordovician. In each instance the two parts are separated by sea-withdrawal and a corresponding hiatus that was followed by another invasion which differed chiefly in that it fell short of the first.

The break between the Medina and the Clinton is comparable in kind and rank to that separating the Trenton from the Eden. Indeed, many simulating features might be cited, but it is scarcely necessary to do so. In view of the already typically Silurian expression of the late Medina (Brassfield) fauna it is inconceivable that any paleontologist would consent to placing the Ordovician-Silurian boundary at the top of the Medina. Apparently, then, we have no choice but to draw it at some lower break.

THE PROPER HORIZON FOR THE ORDOVICIAN-SILURIAN BOUNDARY IN NORTH AMERICA.

The reasons, physical and faunal, why the Richmond-Albion break is unsuitable have been given; and no less valid objections have necessitated the rejection of the Trenton-Eden, the Eden-Maysville, and the Fairview-McMillan breaks. Only the Maysville-Richmond break has the diastrophic qualities to fit the requirements. This conclusion being in entire harmony with the result of the faunal comparisons, I propose to recognize the break between the Maysville and the Richmond, and between their correlates, as marking the boundary between the Ordovician and Silurian systems in America.

This proposal is made all the more confidently because I believe it accords essentially with the philosphical views of DANA. DANA was not a paleontologist, but he had an excellent grasp of the physical and systematic sides of geology. His judgment seems to have been especially sound with respect to the character and importance of the diastrophic movements at the close of the Ordovician. As is well known, he credits the "birth of the Taconic Mountains," or as he sometimes calls it, "the Taconic revolution," to this time. Indeed, he was so greatly impressed with the taxonomic importance of the facts brought out by personal studies in eastern America that he separated the Paleozoic into two great divisions—Eopaleozoic and Neopaleozoic—at this point.

Of course DANA did not understand the true relations of the Oswego, Medina, and Oneida sandstones to the highly fossiliferous Ordovician and Silurian formations which outcrop on the flanks of the Cincinnati dome. The former, excepting pardonable errors respecting the stratigraphic relations of the Oneida to the other two sandstones, were, in the main, properly classified according to diastrophic criteria. The latter, however, were misinterpreted because of the two very generally prevailing misconceptions regarding their faunal contents. According to the first of these, the fossils found in the rocks of the Cincinnati dome from the base of the Trenton to the top of the Richmond were often said to constitute an indivisible faunal unit. The second arose partly as a consequence of the first and partly from lack of knowledge or misinformation as to what an early Silurian, particularly a lower Medina, fauna actually looked like. Without this knowledge, and in the absence of much other but recently acquired information respecting the shifting of continental seas and the oceanic origin, local development, recurrences, and routes of migration of fossil faunas, it is not to be wondered that science became burdened with a baseless conception of what a late Ordovician fauna should be like. As we now know, the early Medina or Richmond fauna of Ohio and Indiana, though wholly unrepresented in the Pulaski fauna of New York, was yet made to masquerade as a local development or facies of the late Ordovician fauna. And in the course of time similar Richmond faunas, like that in the section of Anticosti island, were also identified as "Hudson River." But there the succeeding faunas showed such easy gradation upward that a middle Silurian faunal bridge was assumed, the post-Richmond beds being erroneously correlated as early Medina to upper Niagara. In other words, wherever in America the detrital rock facies was developed which clearly indicates the great physical changes that have been universally accepted as marking the passage from the Ordovician to the Silurian, the boundary between the two systems was drawn in every instance as low or lower in the scale than is advocated in the present work. It is only in some of the areas of relatively nonclastic sedimentation, like the Cincinnati uplift and Anticosti, in which no other criteria than those afforded by the fossils were adequately considered, that the top of the Ordovician has been placed in part or whole above the Richmond.

Compared with other parts of Paleozoic history, the above briefly described physical changes that occurred during the closing stages of the Maysville and the opening of the Richmond set this time apart as of more than common significance. Earth movements of unusual violence are inferred, the like of which may have occurred before only at the close of the Pre-Cambrian and not again before the close of the Chesterian. Judging from paleogeographic and lithologic criteria the course of events in North America may have been something like this: Stresses originating in the ever active process of suboceanic spreading accumulated in increasing ratio during the closing stages of the Ordovician. Overbalancing the opposing forces which reside in the continents, general emergence of the median parts, and finally, of the whole continent, ensued. Presently, however the rigidity of the shell gave way under the strain, relief coming through the development or accentuation of folds, or by compressive shortening, in the weak marginal tracts. The great median parts of the land at the same time settled back to stages favoring extensive marine invasions. Naturally some warping of the continental surface and corresponding differences in the new epicontinental seas resulted from these crustal readjustments. What happened at this time on the Pacific side of the continent is unknown. On the Atlantic side, however, the broader features of the record seem easily determinable. Here degradation of the newly elevated marginal lands supplied first of all the well-oxidized, mostly red, fine-grained clastics which make up the continental and marine deposits of Richmond age in the Appalachian and Allegheny regions. Revived accumulation of stress during this age was again relieved by further elevation of the marginal lands, especially "Appalachia," the accessibly recorded depositional product of this quickening of erosional processes being the fresher and relatively coarser siliceous material making the Tuscarora and other sandstones of the upper Medina. Complete reduction of the highlands of Appalachia which contributed to the filling of the Appalachian troughs evidently required a long time, relative activity of erosional processes being maintained to near the close of the Clinton when clear waters are locally indicated by limestone deposits. Peneplanation probably was not accomplished before the closing stages of the Cayugan epoch, the Appalachian deposits of that age being fairly pure limestone.

PALEOGEOGRAPHIC STUDIES AND MAPS.

The primary basis of paleogeographic maps lies in the study of fossil faunas and floras. The feature of this study that is important beyond any other in shaping our conclusion is that which relates to the distribution of particular kinds of organisms with special reference (1) to the areal distribution of certain species or varieties or, better still, associations of species of land and water organisms; and (2) to the determination of the location of centres or realms or origin and dispersal of marine life and the varying relations of these centres to each other and, more especially, to the life of the epicontinental basins which at times were filled by overflow from the more permanent oceanic basins. The latter necessitates investigations tending to show the development of indigenous life types in the several realms and the variation in each due to occasional or long-continued facilitation of migration between the realms by the submergence or removal of barriers and consequent modifications in direction and extent of marine currents.

In the further development of paleogeographic studies, referring particularly to the delimitation of land and water areas, other criteria and principles than those strictly pertaining to the organic methods come into play. These other methods are based on phenomena falling under the general designation of diastrophism. Most of them are consequent, or in some way related, to the now almost universally accepted principle of the essential permanency of earth features, such as relative depressions and elevations on the surface of the lithosphere. The general permanency of these depressions and elevations is inferred from the relative frequency of phenomena indicating stratigraphic overlap in areas adjacent to outcrops of early Paleozoic and Pre-Cambrian rocks, and the invariably greater time values of the stratigraphic hiatuses in such areas as compared with those breaks found in areas in which large accumulations of Neopaleozoic and later deposits are preserved. From these facts we naturally infer corresponding recurrences of geographic patterns. In other words, that continental areas thus determined to have the structure of stratigraphic troughs—in which "negative" tendencies prevailed—were ever likely to be occupied by marine waters at times of sea transgressions, while the "positive" areas, against whose sloping flanks the marine sediments thin by overlap, were just as likely to always remain partly unsubmerged. And further—because of geographic and topographic relations, and because of the average trend of geographic modifications inferred from the observed distribution of fossil marine faunas,—that certain of these troughs are more subject to invasion from a particular oceanic basin than are the others which, on the contrary, hold similar relations to some one of the other permanent seas.

By such means, then, we separate the surface of a continent into two kinds of areas: (1) those more or less positive areas that are believed to have been only rarely, if ever, entirely submerged, and (2) those intermediate, relatively negative areas into which the waters of one or another of the oceanic basins flowed when conditions favored such invasion.[1] With this map as a basis, isolated occurrences of any clearly distinguishable fossil fauna are connected by sea-ways with each other and with the oceanic realm in which the particular fauna originated and from whence it invaded the continental basins; and in this manner we produce a paleogeographic map that, however generalized its shore lines, is yet an instructive approximation to actual conditions during the age represented. These maps are not merely faunal maps as claimed by Professor H. S. WILLIAMS. They are that and more, because the evidence of the fossils should always be carefully checked and harmonized with the testimony of the purely stratigraphic and structural methods of determining contemporaneity of geologic events before the result is transferred to the paleogeographic map. On the other hand, however, those who are inclined to be critical should remember that the science of paleogeography is still in its infancy. Our efforts in this direction, therefore, are necessarily and admittedly immature; but their failures are occasioned much less by error or weakness of the criteria used in the construction of the maps than by the lack of unimpeachable detailed information in crucial localities.

Regarding the accompanying Ordovician and Silurian maps it is to be understood that most of the (21) numbered patterns are believed to represent not only genetically differentiable seas but also chronologically distinct stages in the geologic history of North America. When these patterns overlap it is, of course, easy to demonstrate their distinctness. This is the case with respect to Nos. 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, parts of 13, 14, 18, and 21. In the remaining instances the evidence is not conclusive either way. Thus, while No. 4 most probably represents an independent intermediate stage it may finally turn out to be in part the equivalent of either No. 3 or

[1] Two maps indicating the positive and negative areas in North America have been published by Professor CHARLES SCHUCHERT in his *Paleogeography of North America*; Bull. Geol. Soc. America, Vol. XX, 1910.

No. 5, with the chances now favouring the last interpretation much more strongly than the second. The Richmond seas (Nos. 12 and 13) doubtless are composite, both the northern and southern invasions including each two, and perhaps three, slightly different invasions, those comprised in pattern No. 12 most probably alternating in occurrence with those making up No. 13. Patterns 14-21 may represent in part contemporaneous invasions. This seems probable, especially for Nos. 14 15 and 16 and for 17 and 19, and possibly 21. The more than usually composite patterns designated Nos. 18 and 21 almost certainly include stages that are distinct from all the others. The chronologic relations of the Pacific invasions to those from the other three sides of the continent are more than usually uncertain. All that we may say of them now is that they occurred subsequent to the Richmond and probably before the Lockport stage of the Niagaran. They may then be either late Medinan or Clinton; or they may include representatives of both of these eastern stages.

The immediate purpose of the maps is to give a graphic illustration of the displacement of the strandline in North America occasioned by diastrophic movements during the latter half of the Ordovician and the early half of the Silurian. Stages 1-11, beginning with the middle and most characteristic ages of the Ordovician (Black River and early Trenton stages) and ending with the McMillan, show especially two features, (1) tilting of the continental platform so that the oceanic waters invaded the land basins occasionally from the east, at other times from the north, once from the Pacific, and oftenest from the Gulf; (2) they illustrate the pulsating progress of the battle between the land and the sea, the latter attaining its greatest advances during the earlier stages, lesser ones during the late Trenton and Eden stages, and finally being driven out entirely at the close of the McMillan. The succeeding Richmond stages quickly established tremendous transgressions which differed not only in areal extent from their immediate Cincinnatian predecessors but also in reaching areas, notably, western Texas[1] and New Mexico, that had not been submerged by any Ordovician sea.

It is to be noted, further, that very important geographic changes occurred at this time also in the Appalachian region. As is well-known, Ordovician marine deposits are generally distributed through the Appalachian valley. Following the Fairview age, however, this entire tract south of Quebec was raised above sea-level; and this condition continued with occasional and but local exceptions in east Tennessee and Alabama throughout Medinan time. Clastic deposits of McMillan and Medinan ages are found in the middle and northern parts of the Appalachian Valley tract but they

[1] Limestone in the Franklin Mountains of western Texas, determined on my authority as of Trenton age, has been described by RICHARDSON (U. S. Geol. Survey, Folio No. 166, 1909). Information acquired in the past two years by Dr. EDWIN KIRK and in part verified in the field and office by myself, makes it clear that the whole of the Montoya limestone, the lower part of which had been supposed to represent the Trenton, is really of Richmond age. Apparently we have here another example of the recurrence of Ordovician types, in dominant numbers and but slightly modified form, following the first appearance of a typical Richmond fauna.

contain no fossils except burrows and are believed to be of continental rather than marine origin. Eastward transgression of marine waters is indicated, except in Tennessee where the opposite condition obtained, by the distribution of Clinton deposits. These are generally present in the western ranges of the valley to the north and south of the excepted area. This partial advance, however, gave way to retreat apparently affecting the whole line, no deposits whatever being known in the Appalachian region that may be justly referred to the post-Clinton stage of the Niagaran.

Thus, it appears that following the pulsating retreat of the closing Ordovician seas, a new dispensation set in with the Richmond invasions. The new conditions are manifested by a rearrangement of land and water areas whose average expression, beginning with the Richmond and ending with the Cayugan, is markedly different in the Appalachian region from that prevailing in the same general area during the Ordovician. The break between the McMillan and the Richmond effectually distinguishes not only the Silurian from the Ordovician but it marks also the dividing line between the sequence of recurrent and therefore closely related geographic boundaries that prevailed through the Eopaleozoic periods from another similarly related sequence that characterizes the composite form of Neopaleozoic epicontinental seas. Evidently paleogeographic studies tend to prove that a revolution, suggested first by Dana on other data, was accomplished during the transition from the Ordovician to the Silurian as here defin.

OBJECT AND SUMMARY.

The object of the foregoing paper is to illustrate the practical and scientific value of the diastrophic method of classification by its application in a well-known and supposedly difficult case namely, the Ordovician-Silurian boundary in America. Before discussing the problem itself the principles of diastrophism are briefly stated. Compared with the older method of faunal matching, in which the age of a fossiliferous deposit is determined by direct and indiscriminating comparison of its fossils with some standardized conception, the comprehensive newer method is shown to be the more practicable and exact. The cardinal principle being dependent on body deformations of the earth whose effect is universally and simultaneously manifested by either negative or positive displacement of the strandline, it is concluded that this method is the only logically systematic and satisfactory one. Applied to the problem of the Ordovician-Silurian boundary, the diastrophic method offers a thoroughly scientific solution of many perplexities regarding which there exist widely divergent opinions among stratigraphers.

In establishing the Ordovician-Silurian boundary all the available evidence, faunal and physical, both in North America and in Europe, is taken into account. In the effort to maintain the original conception of the Ordovician system as far as possible, particular care was exercised in correlating the American formations with the typical British sections. The problem is simple enough in such areas as the Ouachita basin in Arkansas, in which the character and sequence of deposits and faunas are much the same as in the British Isles. But it is not at all simple in the interior areas of the continent where unusual stratigraphic elements are introduced and the paleontologic evidence is so different that satisfactory comparisons seem impossible.

The more important of the varying conceptions of the Ordovician and Silurian in North America are discussed in such detail as seemed necessary to bring out their respective points of strength and weakness. The proposed "Cincinnatic" system of SCHUCHERT is rejected because (1) it lacks definite and practical boundaries, (2) the formations included in it are not co-ordinate in aggregate taxonomic value to the other Paleozoic systems, and (3) its construction is inconsistent with diastrophic principles and prevailing practice.

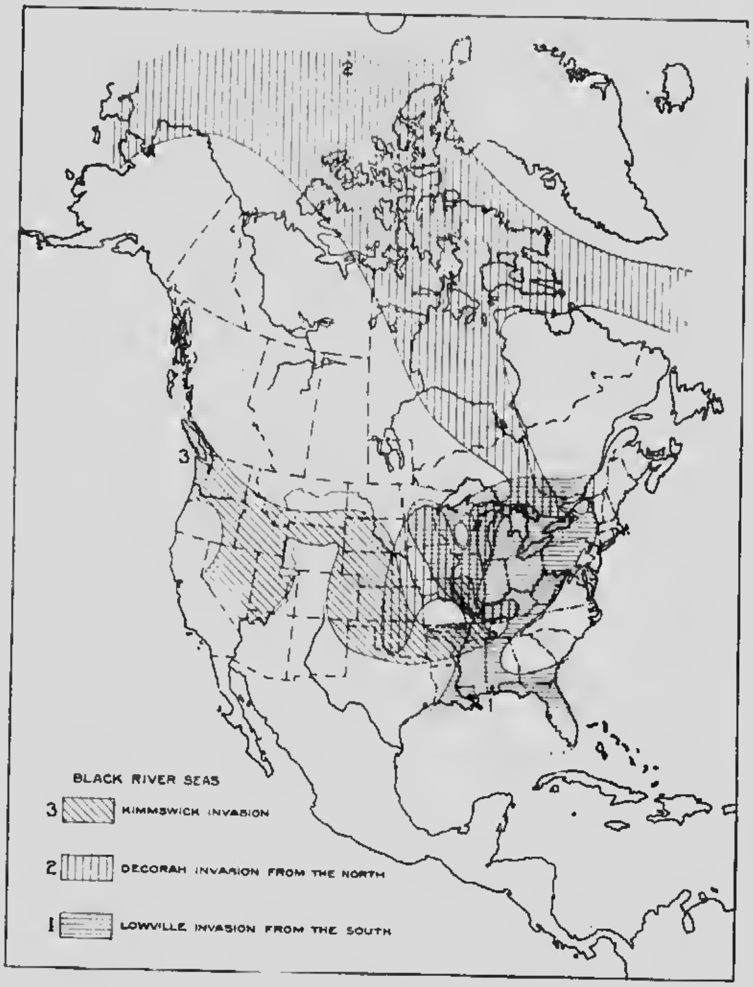
The facts themselves are discussed under two heads: (1) the faunal aspects of the case, and (2) the physical aspects. Both lines of evidence seeming to lead to harmonious results, it was finally concluded that the choice of the Medina (including the Queenston) as the base of the Silurian by the older geologists is a philosophical one, with the weight of available evidence strongly in its favor. Viewed from any angle the choice of the Juniata-Queenston in the east and its contemporary, the Richmond, in the south, west and north, as the base of the Silurian in North America, is the only logical and wholly satisfactory solution of the problem.

In reaching this conclusion the first important step was the decision that the highest beds referred to the Ordovician in Britain are probably older and certainly not younger than the base of the McMillan formation of the Cincinnati section and the top of the Pulaski shale in New York, and that the base of the Silurian, that is, the Lower Llandovery, is not older than late Richmond or, more probably, our upper Medina. Obviously, then the British sections contain no beds representing our McMillan formation and probably none corresponding to our Richmond group. Under the circumstances we Americans must decide for ourselves how these intermediate formations are to be divided between the two systems.

Considering the organic side of the question, which proved exceedingly intricate, it was finally shown that the greatest faunal break between the Trenton and the Niagaran, each the most typical expression of its period, occurs between the close of the Maysville and the beginning of the Richmond. More than 20 typical Silurian genera, also 4 new families, are introduced during the latter epoch. The specific break is almost complete, only some 15 or 20 representatives of persistent types out of a total of 409 Maysville species passing across the line into the Richmond.

This greatest faunal break corresponds also to the greatest physical break. Indeed, there is probably none of greater consequence in the whole of the Paleozoic column. Locally the contact is distinctly unconformable and always it exhibits evidence of interrupted sedimentation and subsequent overlap, the hiatus in many instances being of great time value. The inportance of the break is to be inferred also from the well-marked lithologic differences that commonly distinguish the deposits immediately following the break from those underlying it in areas where such lithologic differences are likely to obtain.

Finally, the harmonious results achieved through the application of faunal, structural, and lithologic criteria are convincingly corroborated by paleogeographic testimony. Comparison of paleogeographic maps representing approximately 20 chronologically distinct late Ordovician and early Silurian stages of North America shows conclusively that beginning with the Trenton, the epicontinental seas of the former period tend constantly to become smaller until at the close of the McMillan age the entire continent must have been emerged. This emergence closed the Ordovician, and at the same time the Eopaleozoic, sequence of events. The succeeding Richmond submergences are not only much more extensive than their late Ordovician predecessors but they differ from them in important details. These, on the contrary, agree much better with the average aspect of Niagaran seas.

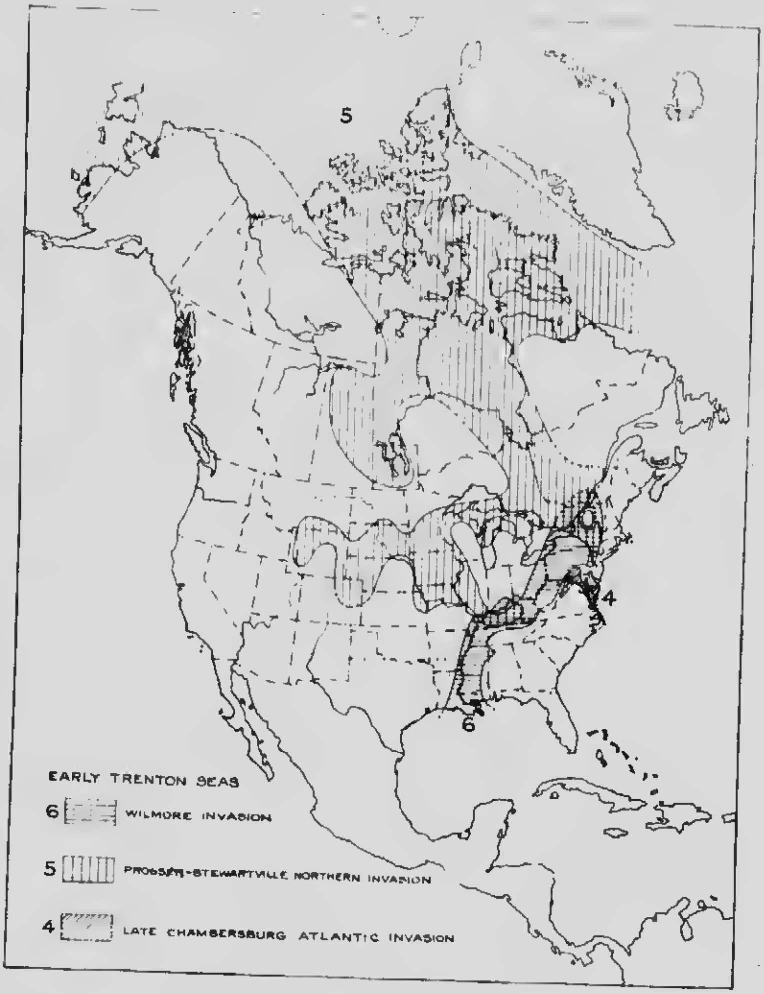


MAP I.

1. Based on deposits of Lowville age, including Lowville limestone in New York, central Pennsylvania, Ontario, Michigan, Kentucky (Tyrone limestone), central Tennessee; corresponding deposits in the Appalachian valley included to the north in the Chambersburg limestone, to the south in the Chickamauga limestone; upper part of the Izard limestone in Arkansas; Plattin limestone in Missouri; main part of the Platteville limestone in the upper Mississippi valley.

2. Based on chiefly shaly deposits correlated with the Decorah shale of Iowa and Minnesota: Baffin Land, Lake Nipissing and other localities in British America, Wisconsin, Michigan, and Oklahoma. Also thin beds in eastern Missouri, north-central Tennessee, central Kentucky, and north-central New York, included with Trenton or Black River formations.

3. Limestones in southwestern Tennessee, northern Arkansas, Oklahoma, deep wells in Kansas, central Colorado (lower part of Fremont limestone), and Montana correlated with the Kimmswick limestone of eastern Missouri and southern Illinois.

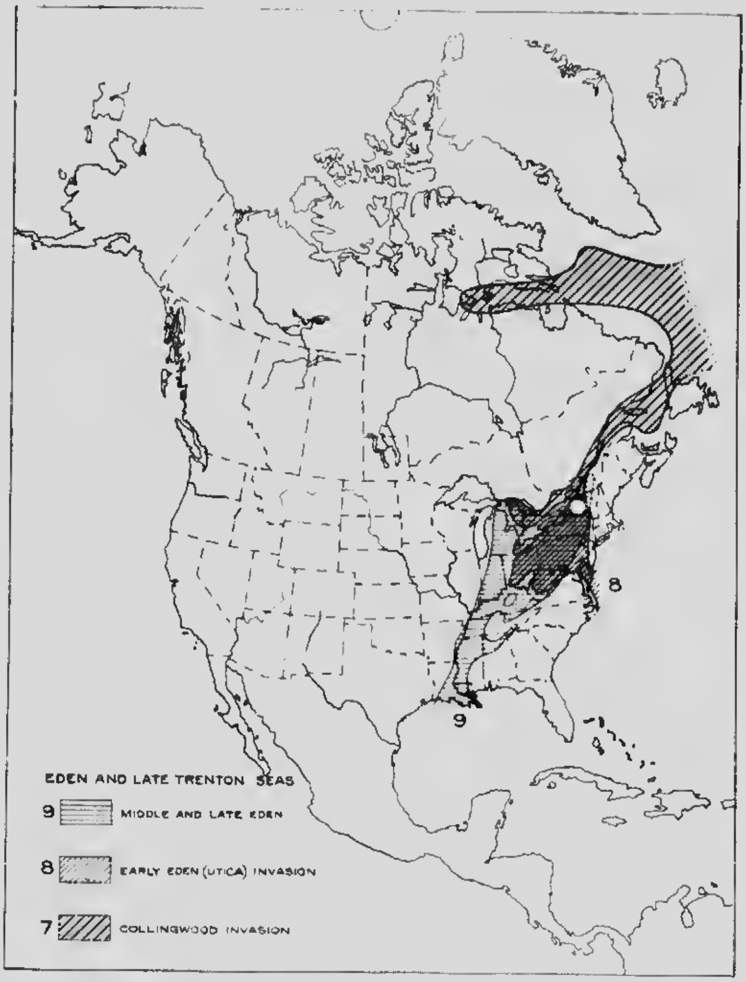


MAP II.

4. Based on the distribution of the Atlantic fauna in the upper members of the Chambersburg limestone in southern Pennsylvania and adjacent parts of Maryland, Virginia and West Virginia.

5. Based on the distribution of the faunas of the Clitambonites, Nematopora and Fusispira beds of the Minnesota section, described in Vol. III, pts. 1 and 2, Final Report Minnesota Geological Survey: found at many localities in British America between Baffin Land on the north, Lake Winnipeg on the southwest, and Montreal on the southeast; occurs in the United States in the lower part of the Trenton limestone in New York, the upper part of the Jacksonburg limestone of New Jersey, Trenton limestone of northern Michigan, the Curdsville limestone of Kentucky, in unnamed limestone in northeastern Missouri, the Bighorn limestone of Wyoming, and probably in the Fremont limestone of Colorado.

6. Based on provisionally correlated occurrences of the middle Trenton facies of the *Prasopora simulatrix* fauna: found in the Wilmore formation of central Kentucky, and in beds of the Trenton in central Pennsylvania and New York, and in the Ottawa Valley region of Canada.

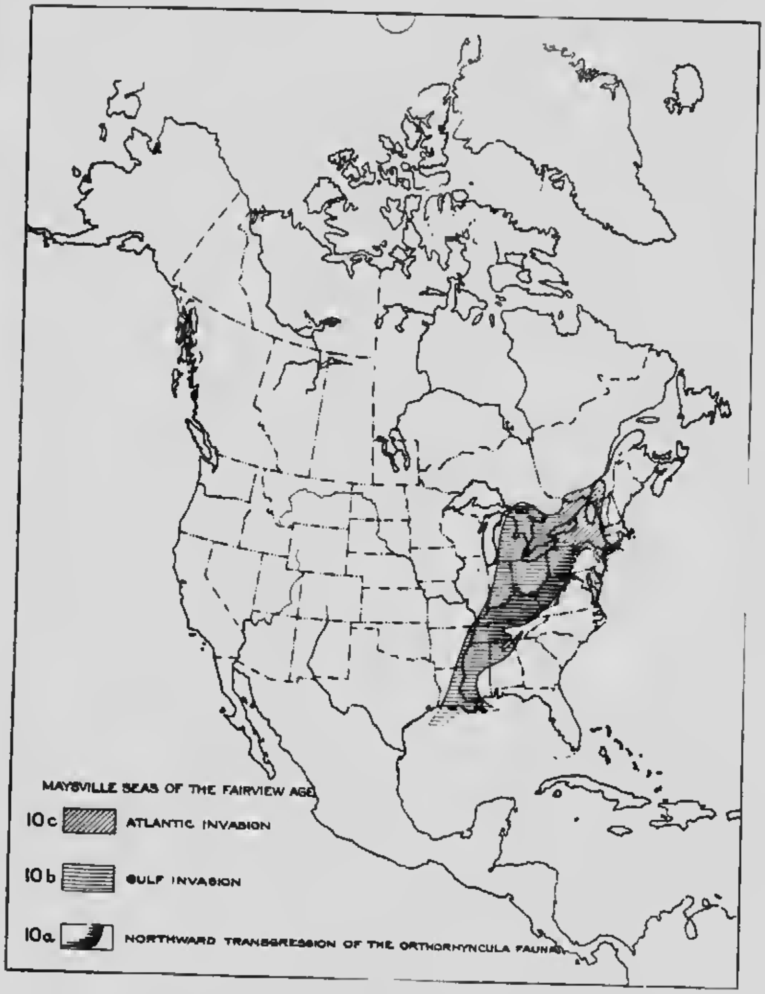


MAP III.

7. Based on the occurrences of black shale in the Ottawa and St. Lawrence valleys containing *Orthograptus quadrimucronatus* and other fossils of the *Ogygites canadensis* fauna, typically developed in the Collingwood shale of southern Ontario.

8. Based on the distribution of black or gray shales thought to be continuous with the Utica shale of New York. In the Appalachian region this horizon is included in the Martinsburg and Reedsville shales. It extends westward to Cincinnati, where it is known as the Fulton shale.

9. Based on occurrences of calcareous shales containing the *Dekayella ulrichi* fauna: found in southern Ontario (included in Lorraine or Hudson shale), New York (Frankfort shale), Pennsylvania and Virginia (middle parts of Martinsburg and Reedsville shales), southern Virginia and east Tennessee (Eden or "Sevier" shale), north-central Kentucky, Ohio and Indiana (Economy, Southgate and McMicken members of the Eden shale).

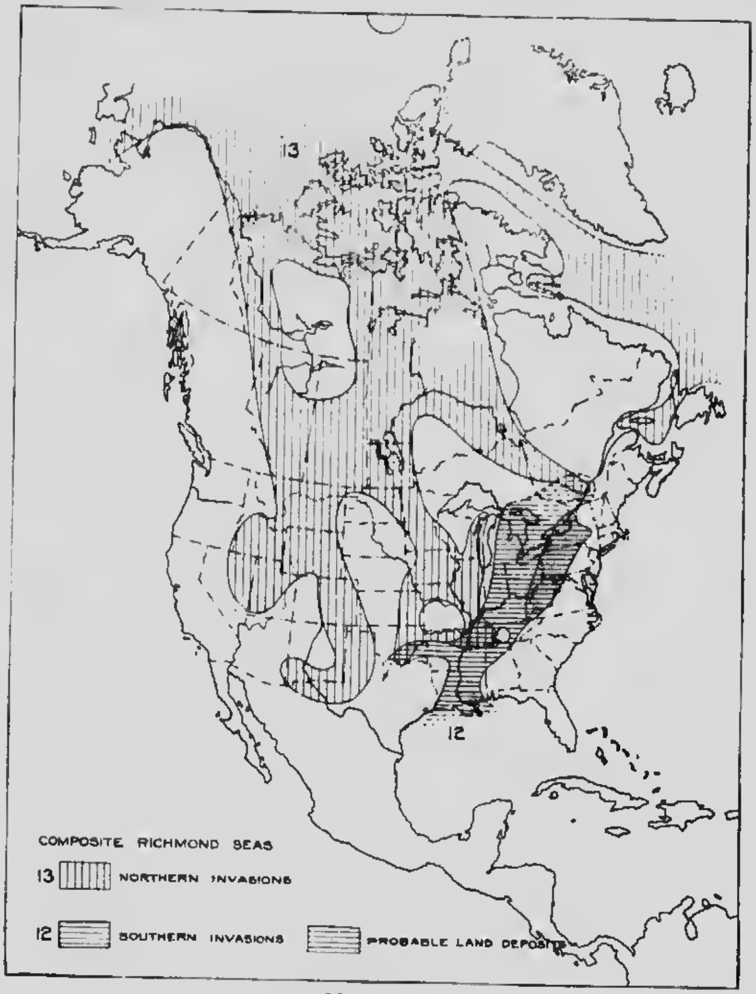


MAP IV.

10. Based on the distribution of beds regarded as correlatable, in part or whole, with the Fairview formation at Cincinnati. *A* represents the known and inferred distribution of the fauna of the *Orthorhyncula linneyi* zone which is at the top of the formation; *b* is based on occurrences of the Gulf fauna of this age in Tennessee (Leiper formation in central part of state, Fairview formation and "Bays" sandstone in eastern part), Kentucky, Ohio, and Indiana (Mount Hope and Fairmount members of the Fairview formation), and in Ontario (beds included in "Hudson" or Lorraine shales); *c* represents the distribution of the Atlantic *Catazyga erratica* fauna in New York (Pulaski formation) and in eastern Ontario and adjacent parts of Quebec (included in "Hudson" or Lorraine shales).

MAP V.

11. Based on the known and inferred distribution of fossiliferous and unfossiliferous beds correlated in part or whole with the McMillan formation at Cincinnati. *A* represents the probable path and westward extent of the transgression of the early Oswego *Ischyrodonta unionides* fauna from New York and Quebec; *b* represents the partly hidden path of the McMillan Gulf faunas, these, as well as the deposits of this age and sea being now accessible only in the near vicinity of the boundary angle between Ohio, Indiana, and Kentucky and locally in northwestern-central Tennessee; *c*, together with *a*, represents the distribution of the Oswego sandstone facies in New York, adjacent parts of Ontario, and in central Pennsylvania ("Oneida," Oswego and Bald Eagle sandstone of literature); *d* represents the known distribution in New York (basal Oswego sandstone) and Quebec ("Hudson" or Lorraine shale) and the inferred path of invasion of the middle Atlantic facies of this age.



MAP VI.

12. Represents a composite of Gulf invasions during Richmond time, including the Arnheim, Waynesville, Liberty, Whitewater, and Elkhorn stages in Indiana and Ohio, and the equivalent deposits of the same in east Tennessee, where they are united under the new term Sequatchie formation; the Arnheim in west-central Tennessee, the Arnheim, Waynesville or Liberty, and Whitewater in north-central Tennessee and central Kentucky; graptolite-bearing shales in the Blaylock sandstone in west-central Arkansas; the Waynesville, Whitewater, and Elkhorn in southern Ontario; and beds with a Waynesville type of Richmond faunas in southern Quebec.

13. Based on Richmond faunas thought to have invaded the continent at various times from the north. They are recognized in Seward peninsula, Baffin Land, and other places in the far north, in the Stony Mountain formation of Manitoba, in remnants to the south of Hudson bay, and in the St. Lawrence valley, in the English Head and Charleton formations of Anticosti island, in the upper member of the Bighorn limestone of Wyoming, in the upper part of the Fremont limestone of Colorado, in the Fish Haven dolomite of Utah, in the Lone Mountain limestone of Nevada, in the Montoya limestone of western Texas, in the Sylvan shale of Oklahoma, the Fernvale formation of Tennessee, Missouri and Illinois, the upper part of the Polk Bayou limestone of north Arkansas, and, more doubtfully, in the Maquoketa shale of Iowa. Minnesota, Wisconsin and Illinois.

MAP VII.

14. Based on the distribution of faunas (particularly *Atrypa marginalis*) characterizing the Girardeau limestone and the Edgewood formation ("Alexandrian" of Savage) of Missouri and Illinois. The Arkansas-Texas extension is based on the presence of early Silurian graptolites in the Blaylock sandstone of the Ouachita geosyncline.

15. Based on known distribution of the Clinch and Tuscarora sandstones in the Appalachian Valley. These sandstones may represent beaches formed at time represented in pattern 16.

16. Based on distribution of the supposedly middle Atlantic upper Medina pelecypod fauna found in the Albion sandstone in New York, the "Cataract" formation at Hamilton and elsewhere in Ontario, and in the Whiteoak Mountain sandstone of east Tennessee. North Atlantic faunas are indicated in St. Lawrence bay.

17. Based on various far western exposures of dolomite containing a peculiar variety of *Pentamerus oblongus*. These are correlated with the Fusselman dolomite of western Texas, and may be either late Medina or Clinton in age. Also includes areas in Idaho containing early Silurian graptolite slates.

CORRELATION OF AMERICAN AND BRITISH MIDDLE AND LATE

SEQUENCE AND PROVISIONAL CLASSIFICATION

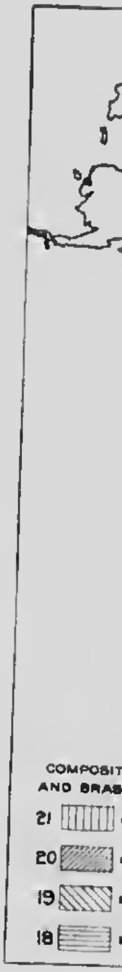
Era	System	Series	Group	Sequence	NEW YORK-ONTARIO	CINCINNATI DOME	APPALACHIAN VALLEY EAST TENNESSEE	APPALACHIAN VALLEY PENNSYLVANIA
NEOPALEOZOIC	DEVONIAN SYSTEM							
	SILURIAN	Cayugan series			Cayugan	(Represented)	Sneedville	Cayugan
		Niagaran	Lockport group		Lockport (including Guelph)	(Represented)	(shaded)	(shaded)
			Clinton	Rochester	Rochester sh. (Clinton)	Osgood		Clinton group
				Irondequoit	Irondequoit ls	(shaded)		
				Williamson	Williamson sh.	Crab Orchard		
				Wolcott	Wolcott ls			
				Sodus	Sodus sh.	(shaded)		
		Medinan	Albion	"Arthrophycus"	Thorold ss (Cataract)	(shaded)	Clinch ss / Rockwood form and Whiteoak ss	Tuscarora sandstone
				Brassfield	Sandstone shale and limestone	Brassfield		
				Noix (Mo)		(shaded)		
				Edgewood (Mo)				
				Whiteoak	Whirlpool ss			
				Girardeau (Mo)	(shaded)			
			Richmond	Elkhorn	Queenston shale ?	Elkhorn	Sequatchie formation	Juniata ss. and shale
				Whitewater		Whitewater (including Saluda)		
				Maquoketa (Iowa)		(shaded)		
				Liberty-Waynesville		Liberty-Waynesville		
				Fernvale (W. Tenn.)		(shaded)		
				Arnheim		Arnheim		
EOPALEOZOIC	ORDOVICIAN	Cincinnatian	Maysville	McMillan	Oswego ss.	McMillan	(shaded)	Oswego (Bald Eagle) ss
				Fairview	Pulaski form	Fairview	Fairview	Reedsville shale / Martinsburg shale
			Eden	Frankfort	Frankfort sh.	Eden: McMicken, Southgate, Economy, Fulton	Eden	
				Utica	Utica sh.			
		Mohawkian	Trenton	Cynthiana	Trenton limestone	Cynthiana	Catheys	Trenton limestone
				Perryville		Perryville		
				Flanagan		Flanagan		
				Bigby		Bigby	Bigby	
				Wilmore		Wilmore	(shaded)	
				Hermitage		Hermitage	Hermitage	
				Prosser (Minn.)		Curdsville	(shaded)	
			Black River group		Black River group	Lowville (Tyrone)	Black River group	Chambersburg
		Chazyan	Blount group		(shaded)	(shaded)	Blount group	(shaded)
			Stones River group		Pamelia ls.	Stones River	Stones River	Stones River
		"St. Peter" series			(shaded)	(not exposed)	(shaded)	(shaded)
	CANADIAN SYSTEM				Tribes Hill ls		Three periods represented by numerous thick formations	(Strongly represented)
	OZARKIAN SYSTEM				Theresa-Potsdam			(Represented)
	CAMBRIAN SYSTEM				(shaded)			(Represented)

Vertically lined shading signifies absenc

...ND LATE ORDOVICIAN AND EARLY TO MIDDLE SILURIAN DEPOSITS

...ATION OF AMERICAN FORMATIONS					BRITAIN	
...ALLEY ...NSYLVANIA	REGION NEW YORK-QUEBEC	ARKANSAS NORTH	ARKANSAS WEST CENTRAL		WALES AND SHROPSHIRE	SCOTLAND
...gan	Cayugan	"Upper St Clair"		SILURIAN	Ludlow group	Representatives of Ludlow and Wenlock
					Wenlock ls and sh	
...linton group	Clinton group	St. Clair ls. (s st)			Woolhope ls. Tarannon sh	Tarannon
					Upper Llandovery	Upper Birkhill
...scarora ...andstone		"Lower St. Clair"	?Missouri Mt shale Blaylock ss 0' to 1500'		Lower Llandovery	Lower Birkhill
...niata ss. ...nd shale	"Richmond"	Cason shale			?	(Probable hiatus)
		Fernvale (Upper Polk Bayou)				
Oswego (Eagle) ss	"Lorraine"			ORDOVICIAN		
...shale / Martinsburg shale	Indian Ladder sh.		Polk Creek shale 25' to 400'			Upper Hartfell sh.
	Utica sh. ?					
	Collingwood sh. Schenectady f. Canajoharie sh.		Big Fork chert 700'		Caradoc ss or Bala	? Lower Hartfell ?
	Glen Falls ls.					
...ambersburg	Amsterdam and other limestones	Kimmswick Lowville				
	Chazyan limestones		Stringtown sh 200' to 900'		Llandeilo shale	Glenkiln sh
...nes River					Upper Llanvirn	?
		St. Peter ss. and ls			?	
...ngly represented	Canadian lss. and sh	(Represented)	Blakely ss 0'-500' Ouachita sh 500'-1000'		Arenig Tremadoc	Skiddaw slates Durness ls
(Represented)	Little Falls Potsdam	Ozarkian			?	?
(Represented)		(not exposed)	Crystal Mt ss Collier sh		Cambrian	Cambrian

...s absence of deposits

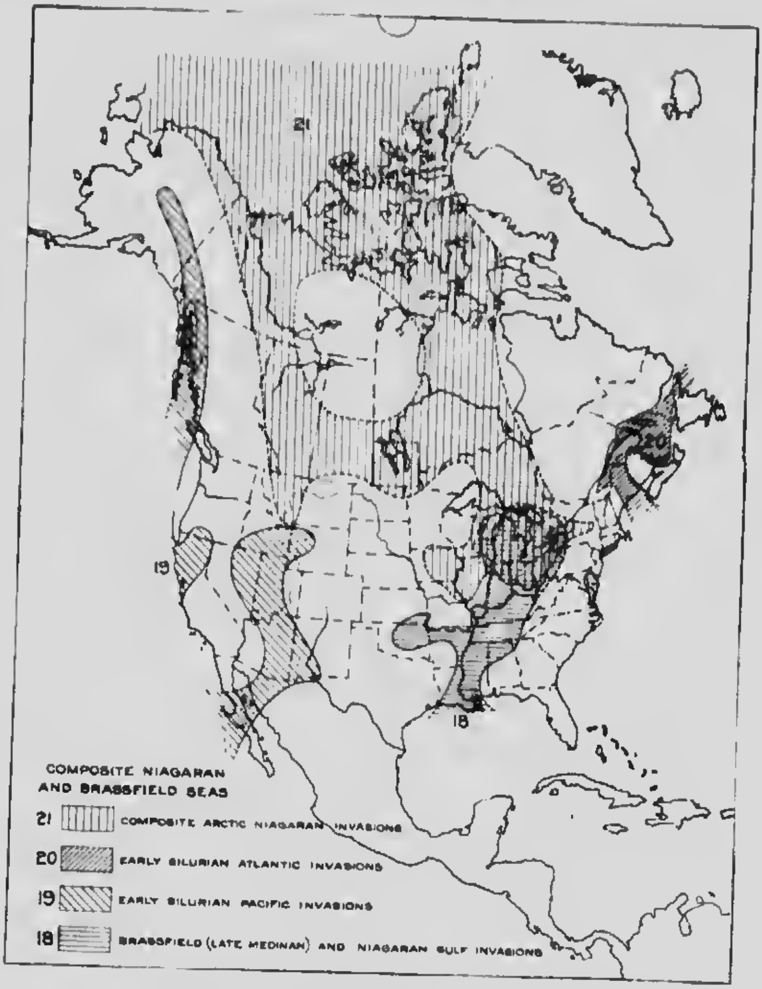


18. Based on
and *Triplecia orton*
oldest of the St. C
in the upper part o
Clinton" or Brassfi
formation of Ontar

19. The same

20. Early Silu
Ellis Bay, Becsie R
Deposits of Medina

21. A composit
north. Based on
Canadian provinces
Lockport age in Ne
Springfield and C
and Missouri.



MAP VIII.

18. Based on occurrences of the southern Brassfield facies of the *Rhinopora verrucosa* d *Triplecia ortoni* fauna: in the basal part of the Hunton formation of Oklahoma, the est of the St. Clair limestones of Arkansas, the Sexton limestone of southern Illinois, he upper part of the Rockwood formation of east Tennessee and Alabama, the "Ohio nton" or Brassfield limestone of Kentucky, Indiana and Ohio, and in the "Cataract" nation of Ontario.

19. The same as pattern 17 on map 7.

20. Early Silurian, probably late Medinan, Atlantic invasions are indicated by the s Bay, Beesie River, Green River, and Jupiter River formations of Anticosti island. osits of Medina and Clinton ages are indicated also in Maine and New Brunswick.

21. A composite representation of Niagaran seas thought to have invaded from the h. Based on numerous outcrops and remnants of Silurian dolomitic formations in adian provinces, and in the United States on similar dolomites containing faunas of kport age in New York, Wisconsin (Waukesha, Racine and Guelph dolomites), Ohio ingfield and Cedarville dolomites), Indiana, Illinois, Iowa (Hopkinton dolomite) Missouri.

DISCUSSION SUR LES CARACTERISTIQUES PHYSIQUES DES MERS PALÉOZOIQUES ET LES PARTICULARITÉS DE LEUR FAUNE CONSIDERÉES AU POINT DE VUE DE LA PORTÉE DU RETOUR DES MERS DANS L'ÉTABLISSEMENT DES SYSTÈMES GÉOLOGIQUES.

H. S. WILLIAMS (Ithaca), referring to the papers presented by Professor SCHUCHERT and Dr. GRABAU, called attention to the difficulty of recognizing the field evidence for diastrophism and the invasion of seas. The final determination of these occurrences seemed to rest with the paleontologist.

He also pointed out that paleogeographic maps, in order to be of value, must represent single planes, for it would be incorrect to represent on the same map portions of a sea that were not contemporaneous. Paleontologists, as Dr. CLARKE had remarked, found difficulty in determining the identity of species, and the use of fossils for making estimates of time was rendered difficult by the fact that some species are very persistent.

He regarded paleogeography as the post-impressionist or cubist phase of geology, in which self-expression is one of the diagnostic features; it seemed likely that this method would fail to obtain uniformity as it had failed in the case of these two gentlemen.

G. R. WIELAND (New Haven): Having listened to all the discussions of the day with an extreme interest, I would also like to add a word of much the same tenor as that of Professor WILLIAMS. This is suggested by my studies of the plants collected in the State of Oaxaca, Mexico, which, I believe, represents the only fairly extended Liassic flora thus far described from the western hemisphere. As you may readily see, the results, if definite, must have an important bearing in the hypothetic location of Gondwanaland in Liassic time; but it is very difficult to determine the species accurately. In general it would seem that resemblances to the European and Indian flora are not sharp enough to indicate a Gondwanaland connection at the time these plants lived. We cannot yet be sure of this but it is clear that accurate determination of faunas and floras cannot be considered any the less important or of any less tangible value.

E. O. ULRICH (Washington), replying to Professor H. S. WILLIAMS, remarked that the recognition of field evidence indicating diastrophic movements and consequent displacements of the strandline is not difficult for those who have made a special study of the phenomena and learned to use the criteria. Though these criteria are both faunal and physical, "the final determination of the occurrences" of sea retreat or sea invasion certainly must not "rest with the paleontologist." The fossils give the clue by suggesting the hiatus and also its approximate time value, but the physical evidence fixes the exact position, shows its character, and often permits us to infer its cause. In short, it rests with the stratigrapher who, to be worthy of the name, must know fossils, and especially their distribution, as well as the physical aspects of stratified rocks.

As to the difficulties experienced by paleontologists in determining the identity of species and also the fact that some species are very persistent, matters referred to by both Dr. CLARKE and Professor WILLIAMS, these may indeed be insuperable to some paleontologists; and if we were to concede Professor WILLIAMS' contention that the final determination of displacements of the strandline rests with the paleontologist, admission of these vital difficulties would establish the perfect logic of his belief that true paleogeographic maps are an impossible accomplishment. But this pessimistic viewpoint assumes incompetence in both the man and his tools.

Continuing, he stated that it is precisely the latter difficulties mentioned by the critic that operated above all other reasons in convincing him of the necessity of finding some more exact method of fixing events in geological history than the but loosely determinative results of faunal comparison. This he declared had been found in the criteria of diastrophism—as recently defined by him—by which definite bo[illegible]mes, marking retreat and subsequent readvance of seas, are recognizable.

Paleogeographic maps should, as said by Professor WILLIAMS, represent single planes. Very few maps of North America so far made strictly fulfill this specification. In fact none can do so so long as paleogeographers fail to realize that these maps are intended to express the areal distribution of contemporaneous deposits and not the distribution of similar fossil faunas, whose occurrence in different parts of a continent may not be contemporaneous at all. The fossils, however, necessary in the first analysis, are but one of several no less essential means of establishing contemporaneities; and all of these must be considered and weighed before a final or even tentative determination is allowable. Maps based on such comprehensive data, he maintained, were reasonably accurate representations of the geography of their times. Doubt in these is justifiable only as regards deposits in wholly-disconnected and widely-separated provinces.

Within the same province faunal evidence alone is usually sufficient to insure a high degree of accuracy. For this purpose the occasional invasion of certain species or varieties, for preferably small associations of species, carefully discriminated from preceding or succeeding invasions of the same forms, and traced out in the field, are of the greatest and most exact service in establishing the areal extent of planes represented in the maps. As an illustration taken from recurring fossils Dr ULRICH cited the case of the late Fairview *Orthorhynchula linneyi* invasion. This fossil is found wherever beds of this age are preserved in Tennessee, Kentucky, Virginia, and thence north in the western Appalachian valleys to central Pennsylvania and always it is associated with other fossils which aid in establishing the exact zone, essentially the exact time of their invasion, and the approximate extent of the continental sea in which they then lived.

Contributions diverses; Explorations recentes.

ÜBER DAS ALTER, DIE VERBREITUNG UND DIE GEGENSEITIGEN BEZIEHUNGEN DER VERSCHIEDENEN TEKTONISCHEN STRUKTUREN IN DEN ARGENTINISCHEN GEBIRGEN.

VON

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Die argentinischen Anden werden im allgemeinen noch heute in allen ihren Teilen als ein junges Störungsgebiet betrachtet, wie der ganze Gebirgswall, von dem sie ein Stück sind. Bis vor kurzem hat man die langen Ketten, die in Südamerika die Küste des pazifischen Ozeans begleiten, für Glieder eines verhältnismässig einförmig zusammengesetzten und einfach gebauten Erdstreifens gehalten. Man hat zwar erkannt, dass sie vor den anderen hohen Gebirgen, die sich in dem letzten grossen Zyklus von orogenetischen Bewegungen gebildet haben, in mehrfacher Beziehung ausgezeichnet sind, und es ist schon früh ausgesprochen worden, dass sich hier auch alte Strukturteile finden. Es ist aber noch nicht gezeigt worden, dass diese alten Stücke zu den letzten, starken Bewegungen ähnliche Beziehungen haben, wie, zum Beispiel, in Asien und Europa die Reste alter Faltungen zu den Alpiden. Ein Teil dieser Beziehungen kann schon heute räumlich und zeitlich begrenzt werden. Ich will versuchen, es hier in den wichtigsten Umrissen zu tun.

Ein Blick auf die Verteilung der Gebirge in dem südlichsten Teile des amerikanischen Kontinentes zeigt, dass sich der östliche Saum des breiten und geschlossenen Andenzuges auf argentinischem Boden in mehrere Erhebungen auflöst. Zum Teil sind es abzweigende Äste, zum Teil abgetrennte Gebirgszüge, die zerstreut aus den Niederungen abflussloser Becken oder aus der Pampa aufragen. Diese Erhebungen finden wir besonders in dem mittleren Abschnitt des Landes, ungefähr von der Breite von Tucuman bis zum Rio Colorado im Süden, und weit entfernt davon und scheinbar ausser allem Zusammenhange mit den Anden, im Litoral der Provinz Buenos Aires, dicht an der atlantischen Küste. Alle diese Gebirgszüge können wir unter der Bezeichnung *pampine Sierren* zusammenfassen.

Wir kommen hier, gleich im Anfang, zu einer alten Frage, die bisher verschieden beantwortet worden ist. Gehören die pampinen Sierren zu den Anden oder sind es selbständige Gebirge von höherem Alter?

Auf D'ORBIGNYS Karte von Südamerika aus dem Jahre 1842,[1] erscheinen sie als Glieder alter Gebirgssysteme, deren Streichen von dem der Hauptandenzüge bemerkbar abweicht. STELZNER, der durch seine grosse Arbeit[2] sehr viel zur Kenntnis der geologischen Verhältnisse von Argentinien beigetragen hat, vernachlässigt den Gebirgsbau, ganz im Gegensatz zu der Gründlichkeit seiner stratigraphischen Betrachtungen; man kann jedoch seiner Darstellung entnehmen, dass er alle Erhebungen in Argentinien zu dem jungen Störungsgebiet der Anden rechnet. Auch die entferntesten Gebirgszüge, die von Buenos Aires, hält er für wiederauftauchende Stücke der pampinen Sierren in dem mittleren Teile des Landes. Diese Meinung hat im wesentlichen auch SUESS vertreten[3] und sie schärfer gefasst, indem er sagte, dass es Äste der Anden seien, die in Virgation von den Hauptstamme nach Südosten abzweigen. Noch in dem letzten Bande seines Werkes *Das Antlitz der Erde* fasst er alle die Strukturteile, die wir hier im Auge haben, unter dem Begriff des andinen Baues, als einer Einheit höherer Ordnung, zusammen. Auf seiner Weltkarte der grossen tektonischen Gebiete wird der andine Bau gegen den südlichsten Teil des Kontinentes rasch breiter; seine nördliche Grenze läuft auf der rechten Seite der Mündung des La-Plata beinahe senkrecht auf die Küste des Atlantik aus. Ich will aber gleich hier bemerken, dass alle Beobachter, die die Sierren von Buenos Aires aus eigener Anschauung kennen, sie in bemerkenswerter Übereinstimmung für Reste alter selbständiger Gebirge halten.

Ich habe die Frage nach der Zahl, dem Alter und der Verbreitung der verschiedenen alten Strukturteile, die man in Argentinien vor wenigen Jahren unterscheiden konnte, schon einmal in einem Vortrage auf der Stockholmer Sitzung des Kongresses kurz berührt.[4] Ich habe dabei hauptsächlich die neuen Ergebnisse der staatlichen geologischen Untersuchungen benutzt. Inzwischen habe ich meine eigenen Erfahrungen erweitert und ich kann heute, unterstützt durch einige wichtige Entdeckungen, ein Bild entwerfen, das vollständiger und in einigen Teilen auch richtiger ist als es damals möglich war. Dabei werden wir zu Ergebnissen kommen, die uns über die Grenzen Argentiniens hinausführen.

Der scheinbar grösste Unterschied der Anden gegenüber den Hochgebirgen des tertiären Zyklus ist das ausserordentliche Mass, in dem alte Gesteine östlich von der Hauptkordillere, nämlich das „Vorland," von einem Teile der tertiären Bewegungen ergriffen worden sind. Einige von den Gebirgszügen, die unzweifelhaft zu der Gruppe der pampinen Sierren gehören, wie der Pié de Palo in der Provinz San Juan und die Sierra de Velasco in La Rioja, erreichen Meereshöhen von 3 000 und 4 000 m. SUESS meint daher, dass diese Erscheinung, in ihrer Grösse, ohne Beispiel sei, und er fasst alle diese Teile, die der tertiären Faltung angegliedert worden sind und die Schichtenfolge der brasilischen Masse zeigen, unter der Bezeichnung

[1] *Voyage dans l'Amérique méridionale, etc.*, Teil III.
[2] *Beiträge zur Geologie u. Palaeontologie d. Arg. Republik*, 1885.
[3] *Das Antlitz der Erde*, Bd. I, III, $_2$, 547.
[4] Compte rendu XIe Congr. Géol. Intern., fasc. 2.

Praecordilleras zusammen.[1] Ihnen steht in deutlicher Abgrenzung das Faltengebiet der andinen mesozoischen Geosinklinale gegenüber, das auf einer langen Strecke, nämlich von der Puna de Atacama im Norden bis zu der patagonischen Kordillere im Süden, die interozeanische Wasserscheide trägt. So scheinen, in der Tat, der altbekannten Einteilung der Anden entsprechend, auch in Argentinien zwei Hauptzüge vorhanden zu sein; die lange und einheitliche Hauptkordillere im Westen und die kürzeren Präkordilleras im Osten, die in mehrere Züge und in vereinzelte Erhebungen zerfallen. Zwischen diesen beiden Teilen liegt im nördlichsten Abschnitt der argentinischen und chilenischen Anden der erst wenig untersuchte Block der abflusslosen Puna de Atacama, der das südliche Ende des bolivianischen Hochlandes, der Altiplanicie, ist.

In meinem Vortrage auf der Stockholmer Sitzung habe ich in den mittleren und nördlichen argentinischen Anden, aus stratigraphischen und morphologischen Gründen, vier Hauptgebiete unterschieden, nämlich:

1. Die *Hauptkordillere*, die zusammengesetzt ist aus mesozoischen marinen Sedimenten und grossen Massen gleichaltriger Effusivgesteine;

2. Das Gebiet der sogenannten *Vorkordillere* in den Provinzen San Juan und Mendoza, das sich unmittelbar an die Hauptkordillere anschliesst und ausgezeichnet ist durch das Überwiegen mariner Ablagerungen des unteren Silurs und Devons und die grosse Verbreitung der kontinentalen Gondwanaschichten[2] vom oberen Paläozoicum bis zum Rhät;

3. Das Gebiet der eigentlichen pampinen Sierren in dem mittleren Teile des argentinischen Andensammes, hauptsächlich zusammengesetzt aus stark kristallinischen präkambrischen Gesteinen und Gondwanaschichten; und

4. Das Gebiet der Puna de Atacama und der östlich davon liegenden Ketten, gekennzeichnet durch verhältnismässig wenig veränderte Sedimente des Präkambriums und marine Ablagerungen des oberen Kambriums und des unteren Silurs.

Zu den stratigraphischen und morphologischen Gründen wollen wir nun die Merkmale fügen, die sich aus der Betrachtung der älteren tektonischen Strukturen ergeben.

Wir haben in den argentinischen Gebirgen als Mittel zur Erkennung und Unterscheidung der verschiedenen, alten Störungsgebiete vier wichtige Diskordanzen, nämlich: (1) eine sehr alte Diskordanz im Norden, an der Basis der oberkambrischen Litoralbildungen; (2) die nächst jüngere an der Basis der älteren Gondwanaschichten, mit Floren der Karharbari oder der Damudastufe, in der Nähe der Anden, nämlich in dem mittleren und östlichen Teile der pampinen Sierren; (3) eine Diskordanz unter jüngeren Gondwanaschichten, die triadische Ablagerungen und Rhät umfassen, in der Vorkordillere von San Juan und Mendoza; und schliesslich (4) die, wie es scheint, auch ursprünglich am weitesten verbreitete Diskordanz an der Basis der

[1] *Das Antlitz der Erde*, III_2. 535.

[2] In Argentinien werden diese Ablagerungen, nach BODENBENDERS Vorschlag, Paganzoschichten genannt.

mesozoischen Schichtenfolge in der Hauptkordillere. Die Verbreitung dieser Diskordanzen fällt mehr oder weniger mit den vier Hauptgebieten zusammen, die wir unterschieden haben.

Im Norden, in den Gebirgszügen der Provinzen Salta und Jujuy, hat die älteste Diskordanz, entsprechend der weit vorgeschrittenen Abtragung der paläozoischen Schichten, die geringste Ausdehnung. Hier sehen wir ausgeprägte Faltung der im Ganzen wenig veränderten präkambrischen Bildungen, die stellenweise bis zur beginnenden Mylonitisierung der eingeschlossenen granitischen Gesteine geführt hat, dann starke Einebnung der gestörten Schichtenfolge vor der Transgression des Oberkambriums.

In dem mittleren und südlichen Teile der pampinen Sierren schien der Zeitraum, der zwischen der Abtragung der Basis und der Ausbreitung der unteren Gondwanaschichten verflossen ist, noch vor kurzem als sehr gross; weil man nämlich die kristallinischen Gesteine der Unterlage im allgemeinen als archaische Bildungen oder doch als Glieder der tieferen Teile des Präkambriums betrachtet hat. Wir wissen aber heute, dass auch hier marine Schichten des unteren Paläozoikums, namentlich die bekannten weit verbreiteten kristallinischen Kalksteine der Sierra von Córdoba, in grossem Masse an der Zusammensetzung der Unterlage beteiligt sind, und dass sie zum Teil in die noch älteren Bildungen eingefaltet worden sind. Hier kann also der Diskordanz der Zeitraum vom unteren Paläozoikum bis zum Permokarbon oder Perm entsprechen.

In der Vorkordillere von San Juan und Mendoza bietet sich die Möglichkeit einer genaueren zeitlichen Bestimmung. Die unteren Gondwanaschichten sind hier nämlich zusammen mit den silurischen und devonischen marinen Bildungen gestört worden. Hier bezeichnet die Diskordanz den Zeitraum vom Perm bis in die Trias.

In der Hauptkordillere, dem Gebiet der gefalteten mesozoischen Bildungen, haben die Transgressionen, soweit wir heute sehen, von Westen her, mit dem unteren Lias begonnen und ihren östlichen Saum im mittleren oder oberen Lias erreicht. Die Unterlage ist hier, wie in der Vorkordillere von San Juan und Mendoza, aus silurischen und devonischen Schichten zusammengesetzt, zum Teil vielleicht aber auch aus präkambrischen Gesteinen.

So können wir, nach diesem Überblick, vier verschiedene tektonische Strukturen unterscheiden: (1) die präkambrische Faltung in dem nördlichen Teile der argentinischen Anden; (2) die Faltungen in dem mittleren und östlichen Teile der pampinen Sierren, aus der Zeit des älteren bis mittleren Paläozoikums; (3) das Gebiet der jungpaläozoischen Bewegungen in der Vorkordillere von San Juan und Mendoza; und (4) den langgestreckten Faltenstreifen der mesozoischen Sedimente in der Hauptkordillere, entstanden durch die faltenden Bewegungen des Tertiärs.

Von diesen Störungsgebieten kennen wir das jüngste, die Hauptkordillere natürlich am besten. Wir sehen es noch heute als eine grosse, gut begrenzte Einheit. Erst im östlichen Neuquen, wo alle pampinen Sierren verschwunden sind, das Gebiet der patagonischen Mesetas und Terrassen beginnt und ein Teil der mesozoischen Sedimente nach Südosten hinausgreift, verklingt die Faltung ganz allmählich. An allen anderen Stellen ist aber ihre Begrenzung gegen die älteren Strukturteile ziemlich deutlich. Dieser Geschlossenheit gegenüber zeigt schon das orographische Bild der Präkordilleras eine grosse Zerstückelung. Zu der Schwierigkeit, die alten Störungen zu verfolgen und ihren Zusammenhang zu erkennen, die sich aus der weitgehenden Abtragung ergibt, gesellt sich der ungünstige Umstand, dass sehr grosse Teile in den abflusslosen Becken und auch an vielen Stellen der Pampa unter einer sehr mächtigen Decke von jüngeren Ablagerungen liegen und so der Beobachtung für immer entzogen sind. Aber durch die Untersuchung der östlichsten Gebirgszüge, der Sierren von Buenos Aires, ist vor kurzem auf den Zusammenhang der Dinge ein unerwartetes Licht geworfen. Wir wollen deshalb ganz kurz zunächst die Verhältnisse dieser Gebirgszüge betrachten und dann versuchen, von hier aus weiterzugehen.

Die Sierren von Buenos Aires, die sich in zwei ungefähr parallelen Zügen von der atlantischen Küste nach Nordwesten weit in das Innere des Landes erstrecken, gehören mit zu den am meisten untersuchten Gebirgen in Argentinien. Über das Alter ihrer Gesteine und ihrer tektonischen Struktur und ihr Alter als Gebirge waren die Ergebnisse der Untersuchungen aber kaum über Vermutungen hinausgekommen.

Es hatten sich, im wesentlichen, drei allgemeine Tatsachen ergeben. Die Sierren von Buenos Aires sind hauptsächlich aus kristallinischen Gesteinen und aus einer Folge von Quarziten, Schiefern und Konglomerat zusammengesetzt, in der an einigen Stellen auch Kalk und Dolomit vorkommen. Diese Schichtenfolge liegt diskordant über der tief abgetragenen kristallinischen Unterlage und hat paläozoisches Alter. Sie ist im südlichen Zuge sehr stark, im nördlichen dagegen wenig gestört worden.

Für unsere Zwecke sind namentlich die Verhältnisse des südlichen Zuges wichtig. Hauthal[1] hat hier einfache Aufrichtung angenommen, mit Zunahme einer sekundären Faltung gegen Südwesten. Die älteste Bildung sollte ein weit verbreitetes Konglomerat sein, darüber sollten Schiefer liegen und hierüber endlich, an dem südwestlichen Saume des Zuges, Quarzite, die hauptsächlich von der Faltung getroffen wurden. Diese Quarzite hat Hauthal mit den ähnlichen Bildungen des nördlichen Zuges verglichen, in denen er bei Balcarce ein organisches Gebilde gefunden hat, das dem *Arthrophycus Harlani*, Hall, aus dem untersilurischen Medinasandstein sehr ähnlich ist. Danach mussten, die Richtigkeit der vermuteten Beziehungen vorausgesetzt, die Ablagerungen des südlichen Zuges unterstes Paläozoikum sein.

Schiller[2] hat indessen schon gezeigt, dass wenigstens die von Hauthal angenommene Altersfolge nicht besteht, sondern, dass sie gerade umgekehrt ist, weil sich nämlich in dem Konglomerat sowohl Gerölle des Quarzits als auch der Schiefer finden. Es war also die Möglichkeit gegeben, wenigstens

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[1] Rev. Museo La Plata, 1892; Publicaciones de la Univers. de La Plata, No. 1, 1901; Peterm. Mitt., 1904.

[2] Sitz.-Ber. k. k. Akad. Wiss., Wien, 1907.

einen Teil der Schichtenfolge als Ablagerungen des mittleren Paläozoikums zu erweisen.

Unter dieser Voraussetzung gelang es mir bei der genauen Aufnahme eines Stückes der nordöstlichen Abdachung der Sierra de la Ventana, im Anfang des Jahres 1910, Fossilien zu finden, die zwar nicht genauer bestimmbar waren, sich aber als unzweifelhafte Reste von Brachiopoden und Zweischalern erwiesen. Hierzu kam ein neuer Fund, den Dr. BEDER und Dr. COLLET im folgenden Jahre machten. Auch hier waren es Brachiopoden, darunter der Rest eines Spirifer. Da mir die Schiefer der Sierra de la Ventana, die zum Teil in Sandstein übergehen oder die Beschaffenheit von Grauwacken annehmen, den devonischen Bildungen in der Vorkordillere von San Juan sehr ähnlich schienen, so lag es nahe, auch in ihnen devonische Sedimente zu vermuten und zwar die Ablagerungen jener weit ausgebreiteten Transgression des unteren Devons, deren Spuren wir heute an weit von einander entfernten Stellen der südlichen Halbkugel finden. Die Faunen dieser Transgression, die ihren Höhepunkt sehr wahrscheinlich in der Zeit der Oriskanystufe erreicht hat, zeigen in Südafrika, auf den Falklandsinseln, in den mittleren Anden Argentiniens, in den bolivianischen Anden und an den brasilianischen Fundpunkten eine ausserordentliche Übereinstimmung. An mehreren Stellen liegen die fossilführenden Schichten zwischen Sandsteinen von erheblicher Mächtigkeit; ganz besonders deutlich in Südafrika und in Bolivien. Es war also möglich, hier einen grossen Sedimentationszyklus vorauszusetzen. Dann konnte der Quarzit der Sierra de la Ventana eine homotaxe Bildung des unteren oder oberen Sandsteines von Südafrika und Bolivien sein. Es war nur ein Schritt weiter, in dem merkwürdigen Konglomerat des südlichen Zuges, auf beiden Seiten des Rio Sauce Grande und in der Sierra de Pillahuincó, das ununterbrochen eine wenigstens 800 qkm grosse Fläche bedeckt, ein Äquivalent des Dwykakonglomerates und des von HALLE[1] entdeckten und beschriebenen glazialen Konglomerates der Falklandsinseln zu vermuten. Eine kurze Reise im vorigen Jahre brachte die Bestätigung durch die Auffindung gekritzter Scheuersteine. Man trifft sie in grosser Zahl, sowohl an den Gehängen der Berge als auch besonders in den Einschnitten der Südbahn nördlich von der Station Sauce Grande. Diese Scheuersteine zeigen alle wesentlichen Merkmale der gekritzten Geschiebe aus den präkambrischen und paläozoischen Blockablagerungen, die heute allgemein für glaziale und umgelagerte glaziale Anhäufungen gehalten werden. Auch das Gestein, das ich hier nicht näher beschreiben kann, stimmt mit dem Dwykakonglomerat von Südafrika überein. Es ist in der Hauptmasse ungeschichtet und enthält Einlagerungen von gebänderten Sedimenten. Es ist im allgemeinen aber so verändert worden, dass es kristallinischen Habitus hat. Ein grosser Teil seiner Gerölle stammt, wie schon SCHILLER bemerkt hat, aus der Quarzitfolge und den Schiefern der Sierra de la Ventana. Sehr häufig sind auch Geschiebe von Eruptivgesteinen: von Gneissgranit, basischen Effusivgesteinen, Porphyrit und

[1] Bull. Geol. Inst. Univ. Upsala, 1911.

Porphyr, deren Anstehendes unbekannt ist. Ausserdem finden sich grüne und rote Schiefer, Dolomit und korallenführender Kalkstein.

Dies Konglomerat wird freilich nicht von jüngeren Sedimenten, wie in Südafrika und auf den Falklandsinseln, überlagert. Es ist aber unzweifelhaft jünger als die vermutlich devonischen Schiefer in der Sierra de la Ventana und, da es, nach seiner Beschaffenheit, als eine alte Bildung betrachtet werden kann und gefaltet worden ist, wie das Dwykakonglomerat in den Kapgebirgen, so vertritt es sehr wahrscheinlich die jungpaläozoischen Moränen, die in Südafrika, in Indien und Australien so weit verbreitet sind.

Ausser den bisher erwähnten Ablagerungen kommt in dem südlichen Zuge noch eine Gruppe von Sedimenten vor, die bisher nur von einigen Beobachtern flüchtig erwähnt, in ihrer Gesamtheit aber noch nicht untersucht worden sind. Es sind grüngraue, zum Teil fleckige Quarzite, dunkle, grüne und rote Tonschiefer, Dolomit und Kalk, die mit einander wechsellagern. Sie setzen den nordöstlichen Saum des südlichen Zuges zusammen und scheinen hier, an dem äussersten Rande, nach einer alten Beobachtung von DARWIN auf kristallinischen Gesteinen zu ruhen. Von ihnen stammt ein Teil der Quarzite, die grünen und roten Schiefer, der Dolomit und sehr wahrscheinlich auch der korallenführende Kalkstein unter den Geröllen des Konglomerates. Obgleich Fossilien noch nicht gefunden worden sind, kann man sie doch am besten mit den untersilurischen Schichten des nördlichen Zuges vergleichen, denen sie in ihrer gesamten Beschaffenheit am meisten ähnlich sind. Hierzu kommt der Umstand, dass in Argentinien nur die Ablagerungen des Untersilurs nennenswerte oder grosse Mengen von Kalk und Dolomit enthalten und beinahe ebensoweit verbreitet sind, wie die Ablagerungen der unterdevonischen Transgression.

Auch das tektonische Bild hat sich, wenigstens im südlichen Zug, durch die letzten Untersuchungen sehr geändert. An Stelle einer einfachen Aufrichtung, wie sie HAUTHAL angenommen, oder einer grossen, nach Norden überkippten Mulde, die SCHILLER vermutet hat, sehen wir auf beiden Seiten der Mittellinie des Zuges entgegengesetzte Neigung der Falten. In dem südwestlichen Flügel ist sie ganz ausgeprägt südwestlich, in dem nordöstlichen Flügel aber nordöstlich. Die Falten sind also gegen den Mittelraum des Zuges geneigt, und diesen Raum nimmt das glaziale Konglomerat in einem langen, nordwestlich streichenden Streifen ein. Seine Unterlage ist bisher nirgends aufgefunden worden. Seine undeutlich begrenzten Bänke sind schwach und in weitem Wurf gefaltet. Nach aussen aber nimmt die Faltung bis an die Ränder der Sierren beständig und erheblich zu. An seinen Grenzen taucht das Konglomerat unter die älteren Bildungen hinab; im Südwesten unter die Schiefer der Sierra de la Ventana, im Nordosten aber unter die Schichtenfolge im nördlichen Teile der Sierra de Pillahuincó, die vermutlich untersilurisches Alter hat.

Untersucht man die Verhältnisse an den Grenzen der verschiedenen Sedimente genauer, so ergibt sich, nach Berücksichtigung aller bisher bekannten Tatsachen, dass die Lagerung der Schiefer und des Quarzites in dem südwestlichen Flügel invers ist. Die Schiefer tauchen unter die Quarzite hinab, und diese vertreten, als die älteste Bildung, sehr wahrscheinlich den unteren Sandstein der grossen Transgression. Sie entsprechen, wenn dies richtig ist, dem Tafelbergsandstein, der in den Kapgebirgen die fossilführenden Bokkeveldschichten unterlagert. Die Verhältnisse an der Grenze zwischen Schiefern und glazialem Konglomerat sind nicht ganz klargestellt. Es scheinen hier Streifen des Konglomerates in die Schiefer eingefaltet zu sein und der obere Sandstein zu fehlen. Vielleicht ist er aber auch in einem Teile der Schiefer vertreten, als eine tonige Fazies. Die Beantwortung dieser Frage muss die Zukunft bringen.

Ich will noch erwähnen, dass im südwestlichen Flügel das allgemein nordwestliche Streichen der Falten gegen Westen, im nordöstlichen Flügel aber gegen Osten zurückbleibt, und dass die Scheitel der dadurch entstandenen leicht gekrümmten Bogen sich nicht gegenüberliegen, sondern etwas gegeneinander verschoben sind. Es gibt auch Anzeichen dafür, dass die Faltung, die ja besonders in die Augen springt, noch nicht den höchsten Grad der Bewegungen anzeigt. Es scheinen auch Überschiebungen von grösserem Ausmaass vorhanden zu sein, deren Hauptrichtung nordöstlich war.

Fassen wir zusammen: in den Sierren der Provinz Buenos Aires, besonders in dem südlichen Zuge, finden wir eine Schichtenfolge, die der in den Kapgebirgen Südafrikas sehr ähnlich ist. Grosse Übereinstimmung scheint wenigstens bei drei Gliedern vorhanden zu sein: bei dem unteren Sandstein der unterdevonischen Transgression, den fossilführenden Schiefern, die den Höhepunkt ihrer Ausbreitung bezeichnen, und bei einem jüngeren, sehr kennzeichnenden Gebilde, dem glazialen Konglomerat des oberen Paläozoikums. Die untersilurischen Schichten entsprechen vielleicht einem Teile jener Quarzite, Schiefer und Dolomite, die in Südafrika zwischen der kristallinischen Unterlage (Malmsbury series) und den paläozoischen Kapschichten liegen. Der obere Sandstein der Kapgebirge, der Wittebergsandstein, scheint freilich zu fehlen. Sowohl die Sedimente der devonischen Transgression als auch das glaziale Konglomerat sind, wie in den Kapgebirgen, stark gefaltet; und die Bewegung ist hier wie dort in der Hauptsache gegen Norden gerichtet.

In den Sierren ist, als die jüngste Bildung, das glaziale Konglomerat gefaltet worden; in den Kapgebirgen zeigen die Eccaschichten an der Basis der Gondwanaserie (Karrooschichten) noch Spuren der Bewegungen. Jedenfalls sind aber die Dislokationen in den Sierren von Buenos Aires nicht älter als in dem äquatorial verlaufenden Teile der Randgebirge von Südafrika. Es wäre freilich möglich, dass sie tertiäres Alter hätten, wie die Faltung in der Hauptkordillere. Die Vergleichung der Daten, die die vielen Bohrungen der letzten Jahre in der näheren und ferneren Umgebung der Sierren von Buenos Aires ergeben haben, zeigt jedoch, dass rot gefärbte kontinentale und marine Schichten der Kreide, nur schwach gestört durch regionale Bewegungen, an sehr vielen Stellen im Untergrund der weiten Pampabeeken diskordant auf alten Gesteinen liegen, so wie in Südafrika in der Randzone des Kontinentes, die Sedimente der Uitenhageformation auf den gefalteten paläozoischen Gesteinen lagern. In beiden Gebieten können also die hauptsächlichen Bewegungen in dem Zeitabschnitt vom Perm bis zur unteren Kreide vor sich gegangen sein. Auch dieser Umstand bestärkt in der Vermutung, dass die Geschichte dieser, durch den atlantischen Ozean getrennten Störungsgebiete in den wesentlichen Zügen übereinstimmt.

Es zeigt sich hier ein überraschender Zusammenhang; und die Sierren von Buenos Aires, die bisher in ihrer isolierten Lage von den meisten Beobachtern als ein vom Andenbau abweichendes Stück empfunden wurden, werden zu einem neuen Glied in der Kette der Tatsachen, die für den ehemaligen Zusammenhang der alten Kontinentalmasse sprechen, von der wir heute noch grosse Stücke in Afrika und Brasilien sehen. Wenn aber die Präkordilleras die Schichtenfolge dieses Kontinentes zeigen, so können wir erwarten, auch in ihnen an einigen Stellen homologe Strukturstücke der Kapgebirge und der Sierren von Buenos Aires zu finden.

Hier fällt unser Blick sogleich auf die Vorkordillere der Provinzen San Juan und Mendoza, wo wir die Diskordanz an der Basis triadischer und rhätischer Gondwanaschichten kennen. Sucht man hier nach der Übereinstimmung, so ergibt sich das Folgende. Die langen, parallelen Züge in der nördlichen Hälfte der Vorkordillere und die breite Aufwölbung in dem südlichen Teile, der Sierra de Uspallata, sind hauptsächlich aus devonischen Schiefern und Grauwacken zusammengesetzt, in denen sich bei Jachal und an anderen Punkten die Transgressionsfauna findet, die sonst von keiner anderen Stelle der argentinischen Anden bekannt ist. Auch das fossilführende Untersilur zeigt grosse Ähnlichkeit mit dem der Sierren von Buenos Aires. Es ist vertreten durch grosse Massen von Kalk und Hornstein führendem Dolomit und durch Quarzit. Die Sandsteine der devonischen Transgression sind noch nicht sicher nachgewiesen; es scheint jedoch der obere Sandstein, der unbestimmbare Pflanzenreste enthält, vorhanden zu sein. Von den Gondwanaschichten enthalten die unteren Glieder, die zwischen die älteren marinen Ablagerungen eingefaltet sind, die Flora der Eccaschichten; es befindet sich dieselbe Mischung von Formen des Gondwanalandes und der nördlichen Hemisphäre wie in Südafrika. Die Gondwanaschichten über der Diskordanz entsprechen zum grossen Teile vollkommen den Strombergschichten in der Kapkolonie; und die Übereinstimmung wird durch die vielen Decken basischer Effusivgesteine noch auffallender. Das glaziale Konglomerat ist zwar, als solches, noch nicht nachgewiesen worden. Ich bin jedoch beinahe sicher, dass man es in einem Vorkommen der Sierra de Uspallata erkennen wird.[1] Auch in der Vorkordillere gehört die nächstjüngere Ablagerung, ganz wie in Südafrika, erst zur Kreide. Die marinen Sedimente des Paläozoikums und die unteren Gondwanaschichten sind stark gestört worden. An manchen Stellen ist die Faltung bis zur Bildung von Schuppen vorgeschritten, in denen sich die

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[1] Inzwischen habe ich es, in der zweiten Hälfte des Februar dieses Jahres, an drei Stellen der Sierra de Uspallata und an zwei Stellen in dem paläozoischen Unterbau der Hauptkordillere nördlich vom Rio Mendoza gefunden. Auch hat sich dabei herausgestellt, dass hier Deckenbau von alpinen Maassen, aber aus permischer Zeit vorhanden ist.

hellen Kalkbänder des Untersilurs, die dunklen Schiefer und Grauwacken
des Devons und die roten Sandsteine der Gondwanaschichten wiederholen.
Diese Schuppen, sowie ein grosser Teil der Falten, fallen nach Westen ein.
In der Vorkordillere waren die starken seitlichen Bewegungen nach
Osten gerichtet, gegen die widerstehenden älteren Teile, wie in den Kapge-
birgen und sehr wahrscheinlich auch in den Sierren von Buenos Aires.
Wir kommen hier zu unserer ersten allgemeinen Folgerung: *In den*
Kapgebirgen, in den Sierren von Buenos Aires und in der ungefähr 400 km
langen Vorkordillere der Provinzen San Juan und Mendoza, an dem östlichen
Rande der Hauptkordillere, sehen wir Strukturstücke aus derselben grossen
Phase von orogenetischen Bewegungen, die ihr grösstes Mass im Perm erreicht
haben. In diesen drei Gebieten treffen wir dieselbe oder eine sehr ähnliche
Schichtenfolge. Die Unterschiede erklären sich durch Lücken, die zum grossen
Teile wahrscheinlich durch spätere Abtragung entstanden sind. Für die Kap-
gebirge und die Sierren von Buenos Aires ist die Übereinstimmung besonders
durch das glaziale Konglomerat erwiesen. In diesen weit von einander ent-
fernten Faltungsstücken waren die Bewegungen nach Norden oder Osten, gegen
ältere Teile, gerichtet.

Dies führt uns zu einer kurzen Betrachtung dieser älteren Teile. Es
sind die pampinen Sierren an dem östlichen Rande der mittleren argentinis-
chen Anden, und die Reste der präkambrischen Faltung in der Puna de Ata-
cama und den östlich davon liegenden Gebirgszügen der Präkordilleras. In
den pampinen Sierren finden wir die Diskordanz an der Basis der unteren
Gondwanaschichten, und wir erinnern uns, dass hier in der Unterlage, nach
den letzten Erfahrungen, auch marine Sedimente des unteren Paläozoikums
in grösseren Masse gefaltet worden sind. Das gemeinsame Merkmal
dieses alten Gebietes ist das mehr oder weniger deutliche Streichen von
Südosten nach Nordwesten. Auf D'ORBIGNYS Karte ist die Abweichung
von der meridionalen Richtung der Anden aber etwas zu gross angegeben.
Ich will auch hinzufügen, dass unsere Kenntnisse noch nicht ausreichen,
ein Bild zu entwerfen, das hier einigermassen geschlossen ist. Sehr wahr-
scheinlich ist eine weitgehende Interferenz von diesen Bewegungen und
präkambrischen Störungen vorhanden, deren Richtung meridional oder
submeridional ist. Wenn wir aber alle bekannten Tatsachen zusammen-
fassen, so ergibt sich in den Umrissen ungefähr das folgende Bild. In den
pampinen Sierren der Provinz La Rioja, namentlich in den östl ehen Aus-
läufern der Sierra de Velasco, dann in dem nördlichen Tei e der Sierra de
Córdoba, in der Sierra de los Llanos und in den pampinen Sierren der Provinz
San Juan, finden sich die Reste eines breiten Faltenzuges, dessen Streichen
N.W.-N.N.W. ist. In diesem Zuge sind die mitgefalteten marinen Sedimente
von unterpaläozoischem Alter am häufigsten in der südlichen Hälfte. Gegen
seine Mitte nimmt aber die Kristallinität im allgemeinen zu. Es finden
sich sehr viel injezierte Schiefer. Grosse Massen von Granit sind hier,
vielleicht in der Axe des Zuges, bei der Faltung eingedrungen. Sie waren
aber schon n der Zeit der Ausbre tung der kontinentalen Gondwanaschichten
auf grosse Strecken in echten Rumpfflächen entblösst. Über die Richtung

der Bewegungen ist noch nichts sicheres zu sagen. Sie können vor sich
gegangen sein vom Silur bis zum Oberkarbon oder Permokarbon. Vielleicht
haben wir hier Faltungen, die den caledonischen Störungen entsprechen. Es
ist aber auch möglich, dass es spätere aber vorpermische Bewegungen waren.

An diesem alten Störungsgebiet schneiden die jungpaläozoischen Falten
mit deutlicher Grenze ab. Ich habe auf die Bedeutung dieser Linie schon
vor einigen Jahren hingewiesen.[1] Sie folgt beinahe dem Aussenrande der
Vorkordillere, mehr oder weniger in dem Meridian der Stadt San Juan.
Die Sierra del Valle Fertil, die Sierra de la Huerta, der breite, flach gewölbte
Schild des Pié de Palo, nördlich und östlich, die kleinen Bruchstücke der
Cerillos und des Cerro Valdivia südlich von San Juan, sind Teile des älteren
Faltungsgebietes: der kristallinischen oder halbkristallinischen Sierren.
Ihnen gegenüber sehen wir die langen Züge der jungpaläozoischen Falten und
Schuppen aus untersilurischem Kalk und Dolomit und devonischen Schie-
fern und Grauwacken. In ihrem Bereiche ist nirgends die ältere Struktur
gefunden worden; aber ihr Aussenrand scheint zum Teil auf die niederge-
brochenen Stücke der pampinen Sierren aufgeschoben zu sein. Besonders
deutlich ist der Gegensatz bei den Cerillos und dem Cerro de Valdivia, wo
der trennende Streifen von Loess und Schutt nur wenige Kilometer breit ist.

Die präkambrische Faltung tritt hauptsächlich in der Puna de Atacama
zu Tage, aber auch östlich davon, in einem grossen Teile der Gebirgsketten,
die bis hinunter nach Tucuman die Niederung des Gran Chaco begleiten.
Die altpaläozoischen Sedimente sind hier nur in dem nördlichsten Abschnitt
bekannt. Sonst breiten sich an den meisten Stellen über den zerstörten
und abgetragenen präkambrischen Sedimenten die roten, teils marinen,
teils kontinentalen Ablagerungen der Kreide aus. An dem östlichen Rande
der Puna de Atacama und in dem westlichen Teile der Provinz Salta
beobachtet man oft nordwestliches Streichen der alten Gesteine; im Süden
dagegen, in den Ausläufern auf der Ostseite des Cerro Aconquija, Streichen
zwischen N.O. und N.N.O. Über den möglichen Zusammenhang dieser
beiden Hauptrichtungen, die so oft auf der Erde wiederkehren, haben wir
noch keine Beobachtungen. Vielleicht war hier ein gegen Osten gekrümmter
Bogen vorhanden. Es scheint mir aber wahrscheinli[illegible] dass die nord-
westlich streichende Faltung in Salta, aus dem Block d[illegible] Puna de Atacama
heraustretend, sich frei nach Südosten fortsetzt.

Es fällt jedenfalls auf, dass gerade das nordwestliche Streichen auf
argentinischem Boden in den alten Strukturen so sehr hervortritt, dass es
schon die Aufmerksamkeit der ersten Beobachter erregt hat. Man trifft
es auch in Bolivien, nach Evans[2] Untersuchung auch im Tiefland nördlich
von der Beugung der Anden bei Santa Cruz de la Sierra, in den alten Ge-
steinen der Stromschnellen des Rio Beni und des Rio Mamoré; dann in der
Niederung des Gran Chaco in den Llanos de Chiquitos. Dazu gesellen sich
in Argentinien die Stücke in der Puna de Atacama und in den mittleren
pampinen Sierren; schliesslich sehen wir es weit draussen, im Südosten.

[1] Sitz.-Ber. k. k. Akad. Wiss., Wien, 1907.
[2] Quart. Journ. Geol. Soc., 1906.

auf dem linken Ufer des Rio de La Plata, westlich von Montevideo und in den Sierren von Buenos Aires; und man darf sich mit EVANS fragen, ob nicht in dem Bogen des Feuerlandes und der Staaten-Insel der Einfluss einer alten Störungslinie hervortritt. Auch auf den Falklandsinseln ist das Streichen der gestörten devonischen Schichten nordwestlich.

Soviel ist jedenfalls sicher, dass die alten Strukturen die im allgemeinen meridionale Richtung der tertiären andinen Bewegungen oft abgeändert haben. In dem Gebiet der ausgesprochenen tertiären Faltung, dem geschlossenen Zug der Hauptkordillere, sind die Interferenzen oder Anpassungen freilich selten. Dagegen sind sie häufig in dem breiten Streifen der regionalen, hauptsächlich aufwölbenden Bewegungen des Tertiärs, durch die die Gebirgszüge der Präkordilleras vor allem entstanden sind. Die Anpassung an ältere Linien hat sich mehrere Male wiederholt. In den nördlichen argentinischen Anden stimmt die Richtung der präkambrischen Falten mit den Störungslinien in den Llanos de Chiquitos überein, deren Alter freilich nicht genauer bekannt ist. Den präkambrischen Bewegungen in den nördlichen argentinischen Anden folgen mit demselben Streichen die alt- oder mittelpaläozoischen Faltungen in dem mittleren Teile der pampinen Sierren; und im Südosten sehen wir dieselbe Richtung in den Linien der jungpaläozoischen Bewegungen der Gebirgszüge von Buenos Aires.

Die Störung der alten Gesteine in den Stromschnellen des Rio Beni und des Rio Mamoré, vor dem Fusse der Anden in kaum 200 m Meereshöhe, ist sicher sehr alt. EVANS hat hier zwar Gerölle eines vielleicht untersilurischen Spongienkalkes gefunden. Wir kennen jedoch nicht seine Beziehungen zu den kristallinischen Gesteinen. Am wahrscheinlichsten ist die diskordante Auflagerung des im Anstehenden nicht bekannten Gesteines.

Aber wenn auch das Alter der Bewegungen hier unsicher bleibt, so kann man doch, glaube ich, schon sagen, dass in Argentinien mehrere Male, von Norden nach Süden, jüngere Faltungen auf ältere gefolgt sind. Die jüngsten nordwestlich streichenden Bewegungen sind die jungpaläozoischen Faltungen in den Sierren von Buenos Aires. Wir wissen nicht, wie weit sie nach Westen reichen. Aber die meridional streichenden Reste von präkambrischen Dislokationen, die wir an manchen Stellen der mittleren pampinen Sierren treffen, dann die Anpassung der tertiären Falten der mesozoischen Hauptkordillere an die jungpaläozoischen Bewegungen in der Vorkordillere, lassen vermuten, dass vielleicht auch in dieser Richtung eine alte Anlage vorhanden ist.

Betrachtet man die heute bekannten Tatsachen in diesem Zusammenhange, so ergeben sich wesentlich andere Vorstellungen, als sie bisher im allgemeinen geherrscht haben.

Die Falten der mesozoischen Sedimente in der Hauptkordillere sind das jüngste Glied in der Reihe der verschieden alten Strukturen. Die Bewegungen waren auch hier gegen die älteren Teile, also nach Osten, gerichtet. In Argentinien und Chile scheint bis in die Bucht von Arica der Einfluss der jungpaläozoischen Struktur vorzuherrschen, die sich an manchen Stellen auch in der Hauptkordillere, in der Unterlage der mesozoischen Sedimente findet. Von Arica *nördlich wird das nordwestliche Streichen der noch älteren Faltungen massgebend, die weit nach Südosten bis zum Rio de La Plata reichen und senkrecht auf die atlantische Küste abbrechen.*

Einige Fragen bleiben freilich unbeantwortet, namentlich die nach der Verbreitung alter Strukturen im patagonischen Tafellande.

Ich will meine Betrachtungen schliessen, indem ich hervorhebe, dass der grösste Teil der Präkordilleras kein Vorland ist, das durch die tertiären Bewegungen gefaltet wurde, sondern dass hier Teile älterer Strukturen seit der Kreide durch die andinen Bewegungen emporgewölbt wurden, unter Verstärkung der trennenden Becken und unter Verwickelung des Netzes von Sprüngen, die sie oft begrenzen, ganz ähnlich wie bei den Fragmenten der Altaiden auf der westlichen und südlichen Seite der Alpen.

DISCUSSION.

G. STEINMANN (Bonn): Durch den Nachweis eines Zusammenhanges [illegible] den Kapgebirgen und den Gebirgen Ostargentiniens durch Herrn Keidel [illegible] Gebirgsbogen erkannt worden, der das Gebiet der heutigen Atlantic über[illegible] nordatlantische Bogen, der das armorische Gebirge Westeuropas mit der [illegible] verknüpft hat, besitzt im wesentlichen jungkarbonisches Alter. Der südliche Bogen, [illegible] jetzt erkannt ist, ist aber jünger, da das permische Glazialkonglomerat in Afrika [illegible] Argentinien gefaltet und durch Faltung stark verändert wurde. Der jüngste Bogen [illegible] der mittelatlantische; er verbindet den Atlas mit dem Ostende der Kordillere von Südamerika und seine Entstehung fällt in der Tertiärzeit.

FIG. 1.—Tektonische Kartenskizze des südamerikanischen Kontinentes

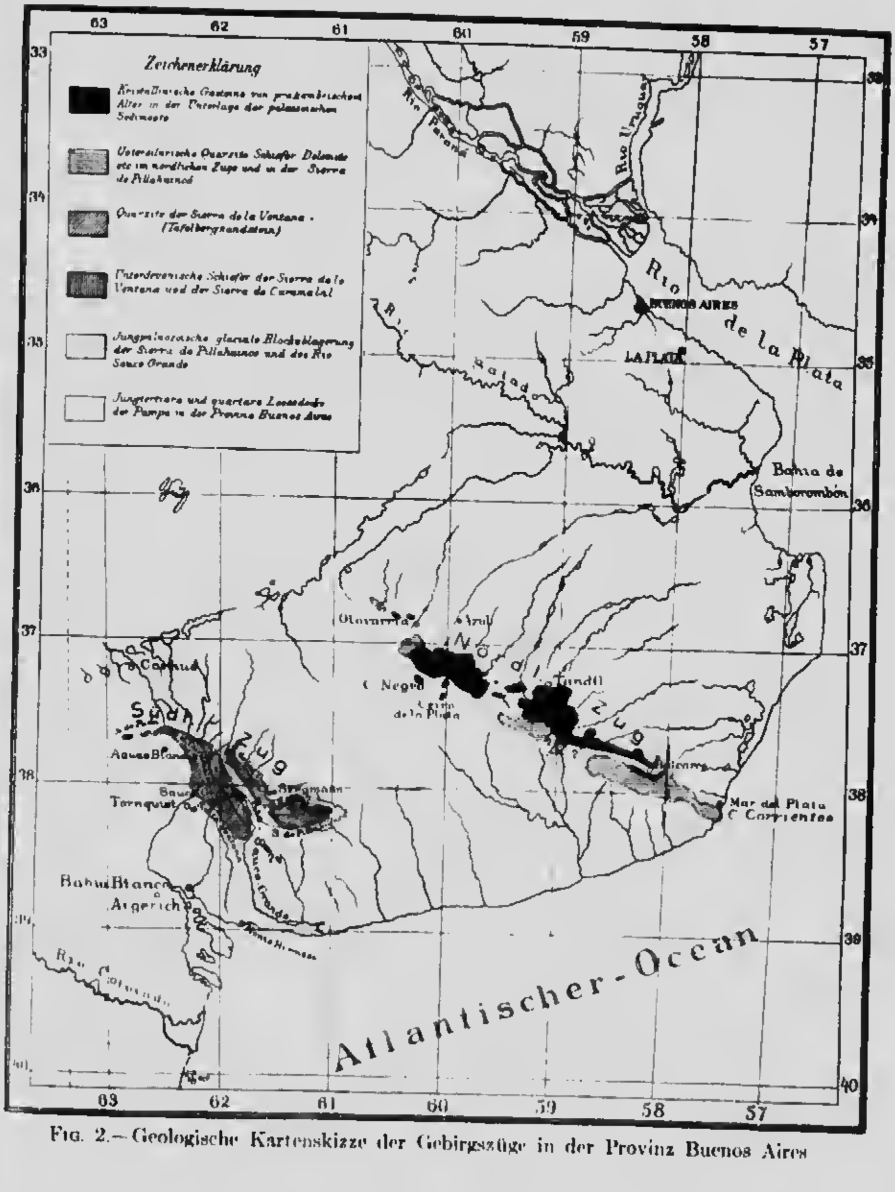

FIG. 2.—Geologische Kartenskizze der Gebirgszüge in der Provinz Buenos Aires

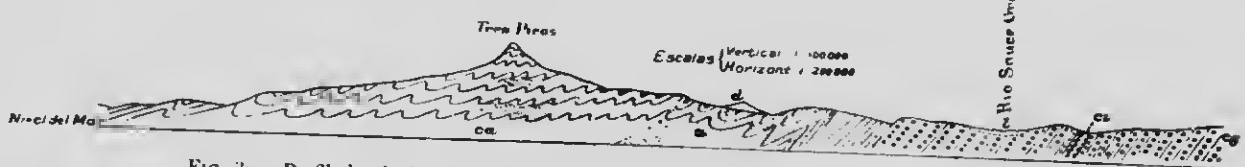

FIG. 3a.—Profil durch die Sierra de la Ventana bis zum Rio Sauce Grande; nach HAUTHAL.

FIG. 3b.—Dasselbe Profil, aber weiter fortgeführt nach N., durch die Sierra de Pillahuincó; nach dem Autor.

Zeichenerklärung: ε = Untersilurische Quarzite, Schiefer, Dolomit, etc., der Sierra de Pillahuincó; ca = Quarzit der Sierra de la Ventana (= Tafelbergsandstein); a = Unterdevonische Schiefer d. Sierra de la Ventana; cg = jungpaläozoische glaziale Blockablagerung der Sierra de Pillahuincó und des Rio Sauce Grande; ci = Zwischensedimente (Quarzit) der Blockablagerung; d = Kontinentales rotes Konglomerat von tertiärem Alter; l = Lössdecke, mit Schottern in den Tälern.

FIG. 4.—Abgeschliffenes u. gekriztes Geschiebe von Quarzit aus der jungpaläozoischen glazialen Blockablagerung der Sierra de Pillahuincó; ¾ d. natürlichen Grosse. 1, von der Vorderseite; 2, von der Rückseite.

FOLDED MOUNTAIN CHAINS, OVERTHRUST SHEETS AND BLOCK-FAULTED MOUNTAINS IN THE EAST INDIAN ARCHIPELAGO.

BY

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With two plates.

Among the islands of the Malay archipelago those belonging to the so-called Timor range or Timor arch, which stretches from Soemba over Timor and Babbar to Ceram and Buru, are much alike in geological structure. Greatly folded igneous rocks and sediments, ranging in age from Permian to Eocene, form the nucleus of all these islands; and this nucleus is more or less, sometimes almost completely covered by Neocene and Pleistocene deposits, which are not folded but are generally elevated to considerable heights above sea-level.

The islands of the Timor range are nearer to the Australian continent (which remained unfolded during the Tertiary period) than any other part of the archipelago except the New Guinea group of islands.

Researches made by J. WANNER in the western section of the Netherlandic portion of the island of Timor and by H. A. BROUWER, F. A. H. WECKHERLIN DE MARES OYENS and myself in the eastern section of Netherlandic Timor as well as in some other islands of the Timor range, viz., Roti, Leti, Moa and Babbar, have shown that during, or perhaps at the close of the Miocene period an intense folding was induced by strong pressure exerted from the north-north-west. This pressure not only greatly disturbed the entire Permian-Miocene strata but also developed imbricated structures and overthrusts of great importance, resulting in a structure which is best known from the Alps and has been called *deckenbau*. Not unlikely, this type of Alpine structure will be found throughout the Timor range, but up to the present it has only been observed in the islands Roti, Timor, Leti and Babbar, that is, in that portion of the Timor range lying near the submarine Sahul bank, which is simply the submerged border of the Australian continent. Thus one might suggest that the resistance, or rather the under-pressure of the Australian continental block, which was not affected by the Miocene folding, caused the overfolding and overthrusting toward the south-south-east in the Timor range.

It is my opinion that at least two overthrust sheets (*nappes de charriage*), in the portion of the island of Timor which I have studied must be distinguished.

Tethys sheet.—The lower of these two sheets (*nappes*), which I propose to call the *Tethys sheet*, is formed principally of oceanic deposits of Triassic, Jurassic and Cretaceous age. Cherts and red clay-shales full of Radiolaria and limestones and marls containing Globigerina form the bulk of these formations. With these formations are abundantly associated limestones and marls of Upper Triassic age composed mainly of shells of *Monotis*, *Daonella* and *Halobia*, but generally containing also Radiolaria and Globigerina. The great majority, without doubt, may be regarded as true deep-sea deposits or abyssites.

Terrigenous deposits are, on the whole, rather rare and local in this complex as, for example, in the district of Fiabarang, where deposits with a limnean facies preponderate over the oceanic deposits. These are characterized by the occurrence of gypsum. In places they resemble petrographically the Flysch of the Alps but, more generally, they strongly recall in appearance the variegated Keuper marls of middle Europe.

Besides these Mesozoic formations there are also in places Permian and Eocene[1] deposits, the Permian formations being the oldest as yet found in the Tethys sheet. These Permian deposits consist of basic effusive rocks tuffs, marls and limestones very rich in fossils, among which corals bryozoa, cystidea, blastoidea, crinoidea, brachiopoda and ammonites are especially abundant and well preserved.

Igneous rocks are found in all the formations of the Tethys sheet, but whereas they are rather rare and of little importance in the Mesozoic rocks they are abundant and characteristic in the Permian deposits. Basic types, frequently more or less completely altered to serpentine, predominate.

The Tethys-sheet formations are found in all parts of the island where the rocks of another sheet that was thrust over them have been sufficiently eroded, except where they are hidden from view by later Neocene or Pleistocene deposits.

The structure of the Tethys sheet is as a rule chaotic. Small complexes or patches of rocks of different ages, each in itself strongly folded and overthrust, form a kind of mosaic, the different masses being separated one from the other by thrust-planes.

Simpler structures are found only in the southern coast-range (the Amanuban and Amanatun mountain chains of Middle Timor). In these hills an imbricated structure prevails, the strata in their repeated succession showing a fairly uniform dip to the north-north-west and the *schuppen* being thrust one over the other in the same direction. (See Plate II.)

A characteristic mountain chain with parallel ranges of hills is well developed only in this southern coast range of the island of Timor. Deposits of Permian age, likewise igneous rocks, are wanting in this coast range.

The sediments of Mesozoic age are all of marine origin and have the character of oceanic deposits; the oldest observed in a few places are claye

[1] J. WANNER has found limestones of Miocene age in strata which he considers to belong to the sheet to which here the name Tethys sheet is given. *Geologie von Westtimor*, Geologische Rundschau, Bd. IV, p. 145, Leipzig, 1913.

marls with *Monotis* of Upper Triassic age. Marly and chalky limestones composed chiefly of tests of Globigerina of Jurassic and Cretaceous age are strongly developed and predominate over all other rocks.

It is somewhat doubtful whether these formations of the southern coast range belong to the Tethys sheet. They may represent its southern margin, which was never overridden by another sheet and consequently, being less pressed, has a somewhat less complicated structure than the rest of the sheet; but it is also possible that these formations belong to a lower sheet or even must be considered as autochthonous.

Fatu sheet.—For the upper of the two sheets I have adopted the name ***Fatu sheet,*** to signalize its most characteristic elements, the peculiar, more or less isolated rocks or groups of rocks, called "fatus" by the natives, that rise abruptly from the usually gentle contoured hills. These isolated rock peaks are so conspicuous that they have greatly attracted the attention of former explorers and travellers in Timor.[1]

The Fatu sheet is, like the Tethys sheet, composed of rocks ranging in age from Permian to Eocene and probably even to Miocene. These deposits, however, present on the whole very different facies from those found in the Tethys sheet.

Among the deposits of Permian age limestones composed almost exclusively of tests of Fusulina, which have not yet been found in the Tethys sheet, are conspicuous in various places. Effusive rocks and tuffs show a prominent and diversified development, the tuffs being in places very rich in beautifully preserved fossils. Marls are scarce but massive limestones full of stems and joints of Crinoids are very strongly developed. Several of the fatus mentioned above are formed of these limestones. In places they are as rich in fossils as the marls of the Tethys sheet but they do not weather out so well and as a rule are not so well preserved. Nevertheless, in some places wonderful collections, especially of brachiopoda and ammonites, have been made from somewhat marly layers in these limestones.

In comparing the Mesozoic deposits of the Fatu sheet with those of the Tethys sheet the paucity of oceanic deposits in the former is very striking. Highly siliceous rocks, as cherts and red clays with Radiolaria, do not predominate over all other types of rocks, as they do in the Tethys sheet. The most conspicuous elements are, on the contrary, masses of unstratified or very indistinctly stratified, mostly oölitic limestones, mainly coral reefs of Upper Triassic age. The majority of the fatus consist of such rock masses ranging in size from a large pebble to masses more than two hundred metres in height and of considerable horizontal extent. They occur either isolated or oftener in groups, forming very rugged hills. Some of the highest and most

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[1] S. Müller, *Bydragen tot de kennis van Timor en eenige andere naburige eilanden;* Verh. over de natuurl. geschiedenis der Nederl. overzeesche bezittingen. Land- en Volkenkunde, Leiden, 1839-1844, pp. 138 en 302.

H. O. Forbes, *Wanderungen eines Naturforschers im Malayischen Archipel;* Bd. II, Jena, 1886, S. 138 und 180.

prominent peaks of Netherlandic Timor, as Mandeo mountain (935 m.), Fatu Naususu (1335 m.) and the peak Fafli Nesi (985 m.) are only fatus. These fatus are in all respects similar to the "klippen" in the Alps or in the Carpathian mountains.

This coral-reef facies of the Upper Triassic does not occur in the Tethys sheet. Limestones with *Monotis* and *Daonella* are found locally in the Fatu sheet but much less abundantly than in the Tethys sheet. Sandstones with remains of plants are also of common occurrence and are probably of Upper Triassic or Lower Jurassic age. These sandstones may also occur in the Tethys sheet, but only rarely. Amphibolite and other schists and also schistose serpentine, all of them probably metamorphosed basic igneous rocks, are of primary importance amongst the constituents of the Fatu sheet. The highest mountains of Netherlandic Timor, for example the Mutis (2365 m.) and the Lakaän (1580 m.) are formed of these schists. These schistose rocks are not found in the Tethys sheet. Also Eocene limestones passing into conglomerates full of *Nummulites* and *Alveolina*, which are not found in the Tethys sheet, constitute an important part of the Fatu sheet. Finally, several types of rocks, the age of which is in many cases not yet known, are found exclusively in the Fatu sheet.

It has not been found possible to differentiate the tectonics of the Fatu sheet, as all the rocks occur in more or less isolated masses, each of which has been folded, thrust and often brecciated by pressure. The more massive and resistant rock masses were evidently pressed one against the other during the intense folding and the less resistant layers between them entirely crushed and squeezed out. Thus more or less isolated masses (fatus) of Permian limestones bearing stems of Crinoids or tests of *Fusulina*, of Triassic oölitic limestone and of serpentine are frequently found in immediate proximity to each other, being separated only by thin, squeezed and thrust layers of various other formations.

The deposits of the Fatu sheet are found as a more or less continuous sheet only in the highest hills of Timor, which together form a strip of country parallel to, and at an average distance of 20 kilometres from, the north coast. Outside this high-lying country the rocks of the Fatu sheet are found only as isolated groups of hills, groups of rocks or quite isolated rocks; all of them either rest upon the Tethys sheet or have been pressed down into the little resistant materials of this lower sheet. I have not always found it possible to separate from each other with certainty the deposits belonging to these two overthrust sheets.

On the north coast there occurs a very thick series of highly tilted igneous rocks comprising basic effusives, especially brecciated serpentines and serpentine-conglomerates which predominate, and tuffs, rhyolites and andesites. They occupy a considerable area along the eastern portion of the north coast of Dutch Timor but end abruptly near the boundary between Dutch and Portuguese territory and no trace of them has yet been found farther eastward in Portuguese Timor. Their geological position is as yet uncertain. They rest upon deposits belonging to the Tethys sheet and may belong to the

Fatu sheet, but they might also represent quite a separate element in the structure of the island.

It may appear hazardous to say that a complicated Alpine structure exists in a territory the stratigraphy of which is still so little known, but the occurrence of groups of deposits of the same age yet of different palaeontological and petrographical character one on top of the other and in close proximity, can not well be explained in any other way. This theory also explains better than any other the frequent occurrence of groups of older rocks resting on younger ones.

A beautiful example of this superposition is found near the sources of the Lassi, one of the tributaries of Oituke river, to the north of Camp Bele. There a group of hills composed chiefly of rocks of Permian age, in which limestones bearing ***Fusulina*** predominate over all other rocks, rests on a very well exposed formation consisting principally of Mesozoic, mainly Jurassic, oceanic deposits and in which Permian rocks are entirely wanting. Beautiful sections all along the deep ravines cut by the Oituke and its tributaries have proved these relations beyond doubt.

Moreover, WANNER[1] in a more western portion of the island and WEBER[2] in a more eastern portion have come quite independently to similar conclusions.

I believe that the observed facts justify the opinion that in the south-eastern portion of the Malay archipelago, that is, at the southeastern border of the great Malay geosyncline a mountain chain of Alpine structure with considerable overthrusts was formed in Miocene time by strong pressure directed from the north-north-west towards the Australian continent.

The period of folding and thrusting mentioned above was most probably followed by a period of prolonged and considerable denudation, because a Pliocene formation rests unconformably upon the much denuded (peneplanated) older formations. The oldest of these Pliocene deposits consist of pure Globigerina limestone, a pelagic sediment devoid of terrigenous elements which must have been formed in an open sea far from land.[3]

During or shortly after the deposition of the Globigerina limestone important crustal movements—this time, however, of a very different type[4]—again set in, which resulted in the forming of basins (geosynclines) trending

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[1] J. WANNER, *Geologie von Westtimor*. Geologische Rundschau, Leipzig, 1913, Bd. IV., p. 136. From this publication I infer that from his observations in the western section of Netherlandic Timor, Dr. WANNER also assumes a structure of Alpine type with overthrust sheets, but his interpretation of the details of this structure differs in many and important points from that given in this paper.

[2] From a verbal, unpublished communication.

[3] I am not inclined to regard this formation as a deep-sea deposit, although it must have been formed in the open sea far from land, but believe that it may have been deposited in the same way as the white chalk of Europe, to which this late Tertiary Globigerina deposit bears petrologically a remarkable resemblance.

[4] For a preliminary description of the bearing of these movements on the geological history of the East Indian archipelago compare G. A. F. MOLENGRAAFF, *On recent crustal movements in the island of Timor and their bearing on the geological history of the East-Indian archipelago*; Proc. Royal Acad. Amsterdam Vol. XV, 1912, p. 224

in a direction approximately parallel to the longitudinal axis of the island of Timor. In a portion of middle Timor, for example, due south of Kapan, a single undivided basin exists which might be termed the median Neocene basin, although generally the structure of the geosynclines is more complicated, being subdivided by ridges or islands of older formations which are also elongated in the direction of the longitudinal axis of the island. Thus in the eastern portion of middle Timor the later Tertiary basin is divided by the Mandeo mountains into two troughs, the Talau-Urnki basin and the lower Benain basin;[1] farther to the west the latter is again subdivided by a narrow ridge of older formations into a northern Benain-Noil-Noni basin and a southern Noil-Lin basin. Flexures of considerable horizontal extent occur at the walls of the geosynclines or "graben," which have caused the Pliocene strata in the basin to become abruptly curved and bent upwards near the edges. In many places a crush-breccia is found between the various older formations and the Tertiary strata, thus indicating the position of marginal fault-planes along which movements have taken place during or perhaps after the formation of the geosynclines. Besides the geosynclinal movement a very slow upheaval of the land probably took place, as is postulated from the character of the successive sediments deposited in the geosynclinal troughs. Since the Pliocene Globigerina deposits at several places, both inside and outside of the geosynclines, are somewhat tilted and disturbed, one may conclude that a certain amount of thrust occurred during the formation of the geosynclinals, although this was much less severe than during the preceding period of intensive mountain-building.

During the formation of these geosynclines by slow subsidence they remained always fairly well filled with an accumulation of late Tertiary sediments, the character of which implies that the sea, although occupying these basins, never attained a great depth. Inside the geosynclines the Pliocene deposits attained a great thickness. In the higher strata of the Globigerina limestone mentioned above terrigenous elements make their appearance and gradually the deposit changes in character and passes into marly and sandy limestones and in places even into a grit with a calcareous cement. Thus the influence of land gradually increases and the higher strata, consisting of marly claystones and marly sandstones, are observed to contain numerous shallow-water shells of Pliocene age.[2] The entire thickness of this Pliocene formation in the geosynclines is unknown but must be considerable, and in my opinion in the Benain basin it may safely be estimated at more than 500 metres.

True littoral formations such as conglomerates, oyster banks, coral reefs, etc., lie directly and conformably upon these Pliocene deposits, and their thickness is at least 200 metres in the central axis of the larger, or

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[1] These two basins are united again west of the Mandeo mountains.

[2] The Pliocene age of these deposits is proved by MARTIN, who has examined the fauna of the marls of Fuhomoro in the Talau basin, which is identical with the fauna of the fossiliferous strata in the basin of the Benain. K. MARTIN, *Tertiär von Timor;* Beiträge zur Geologie Ost-Asiens and Australiens, Serie 1, Band III, p. 305, Leiden, 1883-1887.

Benain basin. One of the coral reefs in the Benain basin is of great thickness (711 metres) and of considerable horizontal extent, being consequently an element of importance in the configuration of the landscape. Over these coral reefs lies a succession of layers of sandstone, conglomerates, oyster banks, etc., all significant of a shallow-water origin. From their considerable thickness we must infer that these deposits were formed during a period of slow subsidence which must have lasted from the Pliocene until the beginning of Pleistocene time.

These reefs and other littoral deposits although becoming thinner toward the edges (walls) of the basins, are not always confined to the geosynclines; in parts of middle Timor they spread over a great area and overlap the older formations, from which they are often separated by a well developed, coarse, basal conglomerate. Consequently they are also found resting unconformably upon the Globigerina deposits where the latter are locally tilted at the edges of the troughs.

In the middle of the geosynclinals there is no break in the succession or visible unconformity between the Pliocene strata and the overlying reefs and littoral deposits, and there can be no doubt that the last mentioned reefs, both inside and outside the geosynclines, all belong to the same continuous formation, the connection of which has been interrupted only by later erosion.

During and just after the formation of these coral reefs a great portion of middle Timor must have been covered by a sea full of coral islands and reefs. The higher mountain groups (Mutis, Lakaän, Mandeo, etc.) emerged as islands from the sea, and conglomerates[1] that were formed simultaneously with and posterior to the coral reefs prove that the islands must have been steep and high and that running water must have transported a considerable amount of débris from them towards the surrounding sea.

It may be accepted that the majority of the big coral reefs of Timor were thus formed in late Pliocene or early Pleistocene times, as they overlie and clearly therefore indicate a younger age than the marls with Pliocene shells.

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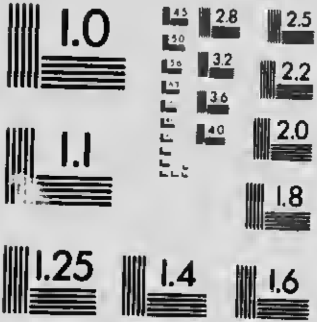
[1] The great majority of the pebbles of these conglomerates, which are of great thickness and occupy a very large area in Timor, consist of amphibolites and other schists, such as are now found only in some of the highest mountain groups, e.g., the Mutis and the Lakaän, which form part of the Fatu sheet. From the abundance of these pebbles one may conclude that, when these conglomerates were forming, the schist formation must have occupied a larger area than it does now. Pebbles derived from rocks of the Tethys sheet of equal or even greater resistance are relatively rare in these conglomerates. In the gravel transported at present by the river the proportions are just reversed, pebbles of amphibolites being scarce and rocks of the Tethys sheet being very plentiful.

And this is just what we must expect if we accept the theory of overthrust sheets. When these Pliocene conglomerates were formed, the rocks of the Tethys sheet in the portion of the island which at that time was not submerged, were still largely covered and protected against erosion by those of the Fatu sheet. Since then the Fatu sheet has been greatly reduced by denudation, and the rocks of the Tethys sheet have been laid bare. In consequence of the uplift the rivers have cut deep gorges in the latter formation and consequently amphibolites are comparatively rare among the pebbles at present transported by these rivers, whereas cherts and even limestones of the Tethys sheet are carried in abundance.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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After these Plio-Pleistocene reefs had been formed a general elevation of the island of Timor took place which possibly still continues. This uprise, however, was not uniform, consequently the elevated coral reefs are no longer found in a horizontal position but feebly sloping.

It appears that the elevation of the central portion of the island has been from the beginning somewhat stronger than that of the southern and northern coastal regions, the entire island thus forming the feebly curved arch of a large anticline.

In fact the reefs of the Dirun ridge, south of the Lakaän and near the central axis of the island, occur now at an altitude of 1283 metres, about 680 metres higher than those in the hills of the north coast at Balilo. Also the big reef of the Gempol cliff in the central portion of the island not far from Kapan lies 1250 metres above sea-level, whereas the highest altitude at which coral reefs are found in the southern mountain ranges near Niki-Niki is only 850 metres.

Moreover, the elevation of the land has been greater at the edges of the basins (geosynclinals) than in the basins themselves. Consequently the coral reefs which rest on the Pliocene strata in the geosynclinals are no longer in their original horizontal plane of deposition, but assume a feebly basin- or trough-shaped attitude and are also split up into blocks of slightly different altitudes.[1]

This latter circumstance may be caused by compression and the squeezing out of the soft and more or less plastic Pliocene strata underlying the heavy, compact, coral limestones, although it might just as well have been caused by a feeble continuation of the crustal movements which caused the formation of the Pliocene *graben* and *horsten*.

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[1] My conclusions differ from those of VERBEEK (R. D. M. VERBEEK, Molukkenverslag. *Geologische verkenningstochten in het oostelijk van den Ned. O.-I. Archipel;* Jaarb. van het Mijnwezen, Vol. XXXVII. Batavia, 1908). According to VERBEEK the coral reefs of the Talau basin are of different age, and were all formed during the gradual upheaval of the land as fringing reefs, which are now found to be the older because of their higher level above the sea (l.c., p. 777).

The highest, those of Dirun ridge at an altitude of 1283 m. above sea-level, he regards as Miocene, those of Lahurus at an altitude of 569 m. as of somewhat later date, and the lowermost, those of Fatu Lamintutu at an altitude of 300 m. as Pliocene. The older these coral reefs are the more they diverge from their original horizontal position; thus the oldest dip 8°, those which are at a lower level dip 5°40′, while those still farther below dip only 3°50′ (l. c., pp. 357 and 778.)

Although admitting that coral reefs are found outside of the geosynclines, and that these reefs now occupy the highest levels, I think that all the elevated reefs, those which occur within the area of the graben, including the Talau basin, as well as those which are situated beyond the limits of the graben, were formed before the commencement of the latest period of emergence (uprise) of the island of Timor and consequently must be of the same late Pliocene or early Pleistocene age. The feebly synclinal and somewhat disturbed and fractured condition of the reefs, which spread continuously over large distances within the "graben", would explain the fact that these reefs are now at different altitudes, decreasing towards the central axis of the graben. An examination of the Foraminifera of these various reefs made by R. J. SCHUBERT has led to the conclusion that they are all of the same age, late Pliocene or early Pleistocene. Thus I have to correct a preliminary assumption regarding their possible age made by myself before this palæontological examination had been made, MOLENGRAAFF l.c., p. 225.

During the prolonged period of recent elevation the running waters were obliged to cut their courses with strong and increasing gradients. Narrow, deep valleys, often true gullies (cañons), which are characteristic of the topography of the greater part of the island, were formed. Numerous terraces are found along the courses of the rivers, both those rivers which have developed their system within the late Tertiary basins and those where the systems lay entirely outside of these basins. This proves that the entire island of Timor experienced the recent elevation, although not everywhere to the same extent.

This differential elevation of the land has generally caused the rivers which flow within the Tertiary basins to cross, somewhere in their course, one or more of the strong layers of reef-limestone at points where these layers are comparatively low. Thus in the central portion of the Benain basin near the native village Neke, at an altitude of 296 m., the Benain has cut a narrow, deep gorge over two miles long through a thick stratum of coral limestone. In one part of this gorge the running water undermined a portion of the coral limestone and thus formed over the stream, which is very deep and strong, a natural arch or bridge which is now a much frequented road.

In the same way Talau river, just below its confluence with the Baukama at an altitude of 245 m.[1] above sea-level, has cut a gorge, now 55 m. deep, across a high bank of coral limestone.

Theoretically one might expect that during this prolonged period of upheaval, which possibly is still in progress, a series of fringing reefs had been formed all round the area of elevation. The current opinion is, of course, that the elevated coral reefs of Timor have been formed in such a way from Miocene time until now, during a continuous elevation of the land.[2] The fact is, however, that not a trace of elevated fringing reefs is found along the northwestern and southeastern coast, where the island of Timor adjoins the eastern continuation of the deep depression of the Savu sea and the equally deep depression of the Timor sea. The westernmost portion of the island, on the contrary, where it borders the shallow water which separates it from the island of Roti, is covered with elevated fringing reefs.

In looking for an explanation of this remarkable fact, it is important to bear in mind that the island of Timor appears to be abruptly truncated and broken off by faults along the northwestern and southeastern coasts, which border deep basins of the sea that reach close up to the shore.

Along the mountain ridge of the north coast, for instance near Balibo, the late Tertiary or early Quaternary reefs and littoral deposits forming the uppermost portion of the Neocene series of the Talau basin, terminate abruptly with their full thickness in a steep cliff that faces the sea at an altitude of about 610 metres. Evidently these strata once extended much farther toward the north, but afterwards became detached. Between this

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[1] VERBEEK, in his description of the Tertiary basin of Talau river, also mentions this gorge; l. c., p. 348.

[2] R. D. M. VERBEEK, l. c., p. 777.

point and the coast no trace of elevated coral reefs is found, yet small reefs of living corals are abundant in the surf of the present beach. This circumstance, as well as the fact that the hills along the north coast rise with an uncommonly steep slope from the sea, tends to prove that the island of Timor is broken off towards the north. Still more convincing evidence is afforded on the south coast, where in the district of Amanatun the parallel ridges of the Amanuban mountain chain, composed mainly of Jurassic and Cretaceous strata striking E. 10° N. W. 10° S. (a direction differing about 12° from the general trend of the coast line), follow each other abruptly, and terminate in high cliffs along the coast. The sea deepens suddenly all along this coast and there are no traces of islands or shoals which might be regarded as the submarine continuation of those ridges. All observations made along this coast support the opinion that the island terminates against a fault facing the Timor sea.

I think it quite possible that the faults which thus terminate the island of Timor both on the north and the south are responsible for the absence of elevated reefs along these elevated coasts.

If we assume the existence of these breaks, the question arises: What has been detached towards the north and the south? Clearly it must be sunken blocks which a e now submerged in the deep basins of the Timor and Savu seas.

North of the island of Timor the eastern continuation of the Savu sea is 3255 m. deep near the island of Kambing. To the south the Timor sea is 3109 m. deep, and this considerable depth is found much nearer to the coast of Timor than to the Sahul bank, which forms part of the continent of Australia.

Timor, however, is not the only island bordered at both sides by deep sea-basins and exhibiting in its raised coral reefs unmistakable proofs of recent upheaval, for the majority, if not all of the islands of the eastern portion of the archipelago, are alike in these respects. Consequently the origin of the deep sea-basins and the elevation of the islands in the eastern portion of the archipelago may be regarded as simultaneous processes between which a genetic connection must have existed.

Adjoining sunken and tilted blocks must have resulted from the same cause, which in my opinion must have been a process of thrust at a certain depth, resulting in very large but gentle folds. Every range of tilted and gently arched blocks or islands, e.g. the Timor range, the Flores range, etc., in this case indicates the position of a saddle, and every range of sunken blocks or deep sea-basins indicates the position of a trough of the gentle but large deep-seated folds, and thus the folding at depth is expressed in the surface topography.

If the question were raised as to what might be seen at the earth's surface if an area were compressed by crustal movement at a certain depth, I should be inclined to reply that its appearance would be similar to what obtains at present in the eastern portion of the Indian archipelago. But adequately to discuss this the submarine topography[1] must also be considered, and fortunately the excellent deep-sea chart of the Siboga expedition makes this possible.[2]

The most salient feature on this map is the striking difference which exists between the western portion (the Java sea and its surroundings), and the eastern portion (the Molucca sea). The latter exhibits a complex topography and great variations both in the depths of the sea and in the heights of the numerous islands, which generally emerge boldly from the sea; whereas the western area shows a slight and very uniform depth of sea and smooth outlines of land, which rises with a very gentle slope from the coast.[3] This western portion, with the gentle topography both of land and sea-bottom, has not taken part in the more recent crustal movements; since the upheaval which raised the Miocene sandstone formation in central Borneo to more than 1000 m. above the sea, no earth-movements have been recorded there, with the probable exception of the area immediately bordering the Strait of Macassar. In the eastern portion of the archipelago, where a complex topography of land and sea-bottom prevails, deep sea-basins have been formed by subsidence; and during the same time ranges of islands have been elevated above the sea by opposed movements which are probably still in course of progress. *It thus appears that in the latest geological period the crustal movements in the geosynclinal or movable area between the*

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[1] In my opinion it is imperative to study the submarine topography, because the area hidden beneath the sea in this archipelago is so much greater than that of the islands. This itself is a favourable circumstance, for the basins have been comparatively little filled by products of land erosion and consequently the surface topography originated by the recent crustal movements has been fairly well preserved at the bottom of the sea. The upraised islands, of course, are smaller and lower now than they would have been had erosion not counteracted the results of elevation. In or near large continents the chances for the preservation of a salient topography are much smaller, because the original features would be much sooner obliterated by erosion and sedimentation. Thus in a portion of northern Germany and the Netherlands, geologically not long ago, crustal movements formed a surface, certainly not less complicated than that of the East Indian archipelago, but subsequent levelling processes have been so powerful that its original topographical details have become so obliterated that at present only traces of them can be seen; indeed the Quaternary and a portion of the Tertiary deposits would have to be removed to show the complexity of this topography.

[2] G. A. F. TYDEMAN, *Hydrographic results of the Siboga expedition;* Chart 1. M. WEBER, *Siboga-Expeditie;* Part III, Leiden, 1903.

Soundings made in the archipelago since the results of the Siboga expedition were published have proved that the submarine topography is even more complex than that shown on the chart. Very probably the most important result of the Siboga expedition, the demonstration of the existence of a strikingly complex submarine topography in the eastern parts of the East-Indian archipelago, will be more accentuated by future researches.

[3] VERBEEK has already drawn attention to this striking difference between the western and the eastern portion of the archipelago and he advocates an indirect cause for the deep sea-basins and the islands with elevated coral reefs (l.c., p. 817). In his opinion the elevation of the islands took place only after the deep sea-basins had already been formed by the subsidence of land masses; pressure exercised by the sunken blocks caused later folding at a great depth, and elevation of the islands (l.c., p. 816). In my opinion, however, the cause was a direct one; the subsidence of the deep sea-basins and the elevation of the islands took place at the same time, and both opposed movements were the results of one and the same phenomenon of thrust and folding at a certain depth.

Australian and Asiatic continents have been confined to the portion immediately adjoining the Australian continent, i.e., between Borneo and Australia.

In tropical regions generally, a coating of coral limestone is formed along an elevated coast as long as there are no causes to counteract or destroy the growths of successive fringing reefs during the period of upheaval.

This easily recognizable coating of coral limestone (series of fringing reefs in different levels, one above the other) in tropical regions affords an excellent criterion for deciding whether a coast has been elevated with reference to sea-level. Now, raised coral reefs have not been recorded[1] in the entire western portion of the archipelago, that is, the land surrounding the Java sea where, according to my opinion, no important movements of the land relative to the level of the sea have taken place in the latest geological time. In the eastern portion of the archipelago with its complicated topography, where crustal movements have occurred, elevated coral reefs are found on the great majority of the islands.

I believe that where a deep-sea chart shows a complicated topography the adjoining coasts must show signs of upheaval.

If my suggestion is correct that folding at a certain depth is the cause of the simultaneous origin of both deep sea-basins and the elevation of the islands, the following phenomena would result:

1. The elevated islands would be grouped in rows, for they are nothing but the elevated though fractured strips of land on top of the saddles of the deep-seated folds. The trend of the rows of islands would indicate the line of strike of such folds, examples of which may be seen in the row Soemba-Timor-Timorlaut-Kei-Ceram-Buru; also Soembawa-Flores-Wetter, etc.

2. The deep sea-basins would be elongated in one direction more or less exactly parallel to the adjoining rows of islands, because they overlie the troughs of the deep-seated folds. For example, I may quote the case of the Savu sea, the depth near the island Kambing, the Timor sea, the Weber depth, etc.

3. Near the surface, in the zone of fracture, one would also expect to find faults which had broken the sides of the folds. Such faults would lie between the deep sea-basins and the elevated islands; and where the faults had repeatedly cut away the land at the coast, the development of elevated, fringing coral reefs would have been hampered. This has taken place both on the north and the south coast of the island of Timor, and also in the islands of Moa and Leti.

4. All the islands of our row would be elevated, but the elevation would be very unequal, as can be observed by comparing one island with another or by examining different portions of one island. This is indeed the case in all the elevated islands, as can be principally deduced from the descriptions in VERBEEK's *Molukken-verslag.*

5. There is no reason why faults should occur between adjoining islands

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[1] Java, especially the southern coast, would have been subjected again to the crustal movements which occurred at the border between the Indian ocean and the East Indian archipelago.

belonging to one and the same elevated range (saddle of a deep-seated fold), which would hamper the development of elevated coral reefs. It is possible that this circumstance might explain why elevated fringing coral reefs appear to be so well developed at the western extremity of Timor.

6. Where the deep-seated fold shows sudden bends or curves, or where two systems of folds interfere,[1] exceptions to the above mentioned rules and complicated cases may be expected. The deep-sea chart of the Siboga expedition shows good examples of this fact.

CONCLUSION.

In the Timor archipelago and probably in the entire southeastern portion of the Malay archipelago, not long ago geologically speaking, two different types of mountain-building followed one another.

The earlier type consisted of intense folding which took place at the close of the Miocene period, culminating in Timor and adjacent islands in overthrusts of great magnitude in a south-south-east direction, and resulting in an Alpine type of structure. The later type originated ranges of islands considerably elevated above sea-level and deep sea-basins bordering those ranges, by opposed crustal movements which are probably still in progress. Thus the two types of mountain-building, which in America are well developed and since the time of GILBERT,[2] known as the Appalachian type or folded and overthrust type, and the Great Basin Range type or block-faulted type, occur in the southeastern portion of the Malay archipelago, in the same area and closely following one another in age. According to my opinion both types of mountains are evidently formed by tangential compression.[3]

In the first instance the compression was very powerful and not deep-seated and is expressed at the surface in the zone of fracture by mountain ranges of Alpine character accompanied by overthrust sheets. In the second instance the compression was deeper-seated and perhaps less energetic and is expressed at the surface by mountains of the block-faulted type, in this case by ranges of elevated islands alternating with deep sea-basins.

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[1] The East Indian archipelago is situated in the area of junction of two systems of folding of the earth's crust, the alpine and circumpacific systems. (vide E. HAUG, *Les géosynclinaux et les aires continentales;* Bull. de la Soc. Géol. de France, 1900, 3. Sér., Vol. XXVIII, p. 635. While Mr. HAUG refers in this area to an "embranchement" of the two systems, SARASIN goes further and speaks of an actual conflict: "Ich habe noch immer den Eindruck, dass es sich im malayischen Archipel um einen Konflikt zwischen den Kettensystemen der Tethys und denen der pazifischen Umrahmung handle." P. SARASIN, *Zur Tektonik von Celebes;* Monatsberichte der deutschen Geol. Ges., 1912., p. 215.

[2] G. K. GILBERT, *Report on the geology of portions of Nevada, Utah, California and Arizona:* Report upon Geogr. and geol. explorations and surveys West of the 100th meridian, Vol. III, 1875. GILBERT's explanations of the probable mode of origin of these two types as given on page 62 of this memoir are not very different from those which I am inclined to accept.

[3] BAKER also considers the Basin ranges as mountains of tangential compression. C. L. BAKER, *The nature of the later deformations in certain ranges of the Great Basin;* Journal of Geology, Vol. XXI, 1913, p. 273.

EXPLANATION OF THE PLATES.

Plate I is a small-scale map, copied with a few corrections from the map published by the Topographical Institute at Batavia.[1] The scale of Plate II is six times larger in scale. This plate represents diagrammatic sections across the island along lines indicated on the map. Some details which are given in the sections, had to be omitted in the map; thus the imbricated structure in the Tethys sheet in the southern coast range is not shown on the map, the entire Tethys sheet being indicated by one colour only.

Amongst the formations belonging to the Fatu sheet only Permian, Triassic and schists are separated; the areas covered by other formations are too small to be shown on so small a scale.

It has been found equally impossible to distinguish on the map the small areas of older formations which in many places make their appearance at the surface through the overlying Plio-Pleistocene deposits; consequently the yellow colour on the map covers an area which is in reality smaller and much less continuous.

The Pliocene deposits underlying the Plio-Pleistocene formation are differentiated in the sections only and not on the map because they are for the greater part hidden by the later deposits.

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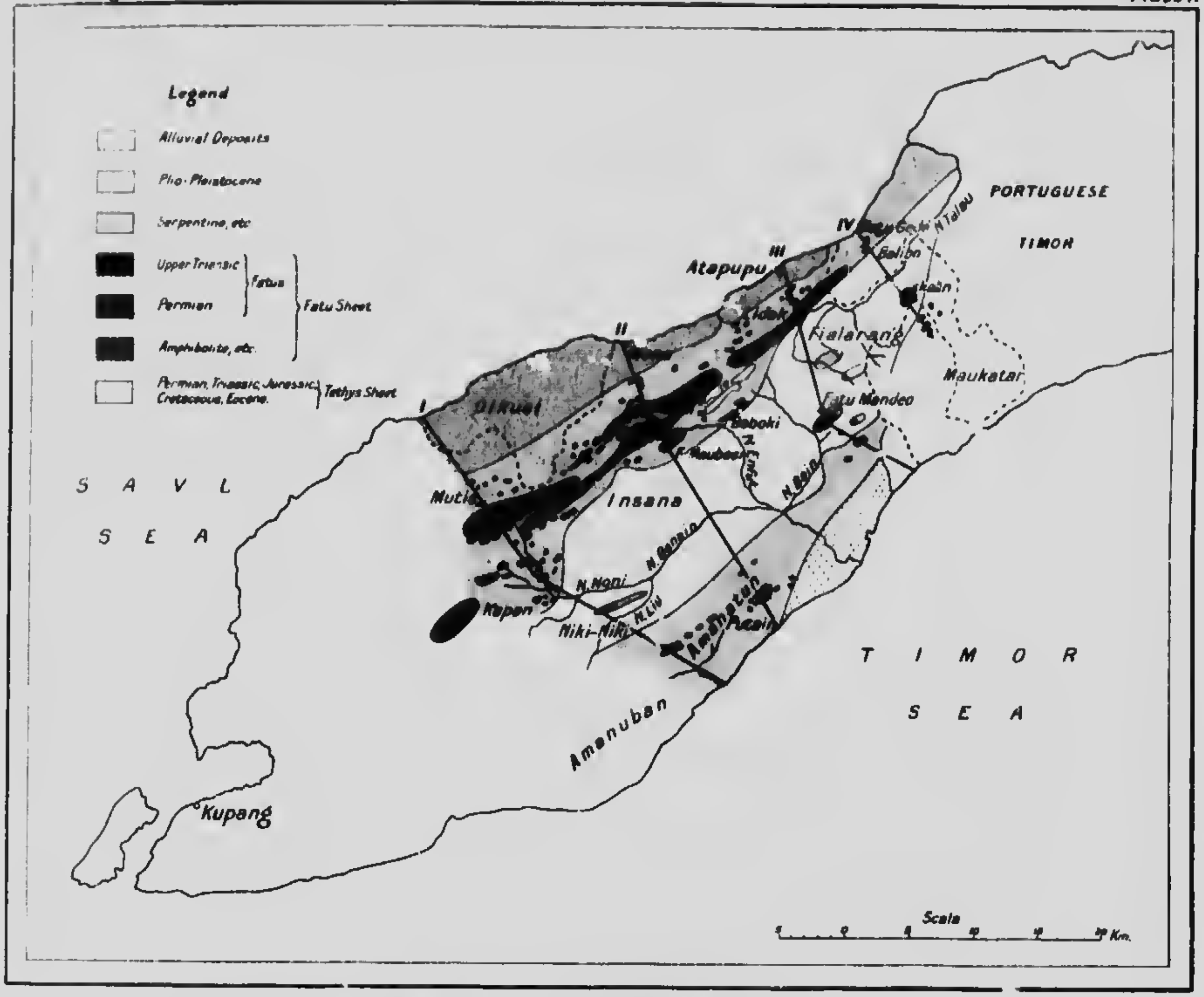
[1] *Schetskaart van Nederlandsch Timor en omliggende eilanden* 1:500.000; Topographische inrichting, Batavia, 1911. The names are spelled in the same way as on the official maps except that for phonetic reasons "oe" has been replaced by "u."

DISCUSSION.

O. A. WELTER (Bonn): Ich bemerke zu dem Vortrag von Herrn MOLENGRAAFF dass die hier vorgetragene Erkenntnis von der alpinen Struktur Timors in erster Linie T. WANNER in Bonn zu verdanken ist, welcher von modernen Geologen als Erster in das kaum pazifizierte Timor eingedrungen ist. Da er der Erste gewesen ist, welcher die grossen Überschiebungen auf Timor erkannt und publiziert hat, so möchte ich nicht unterlassen seine Priorität und seine Verdienste hier ausdrücklich festzustellen. Und wenn heute Herr MOLENGRAAFF die WANNER'sche Auffassung von der alpinen Structur Timors, welche er früher bekämpft hat, heute annimmt, so ist er zu seinem Stellungswechsel aufs Beste zu beglückwünschen.

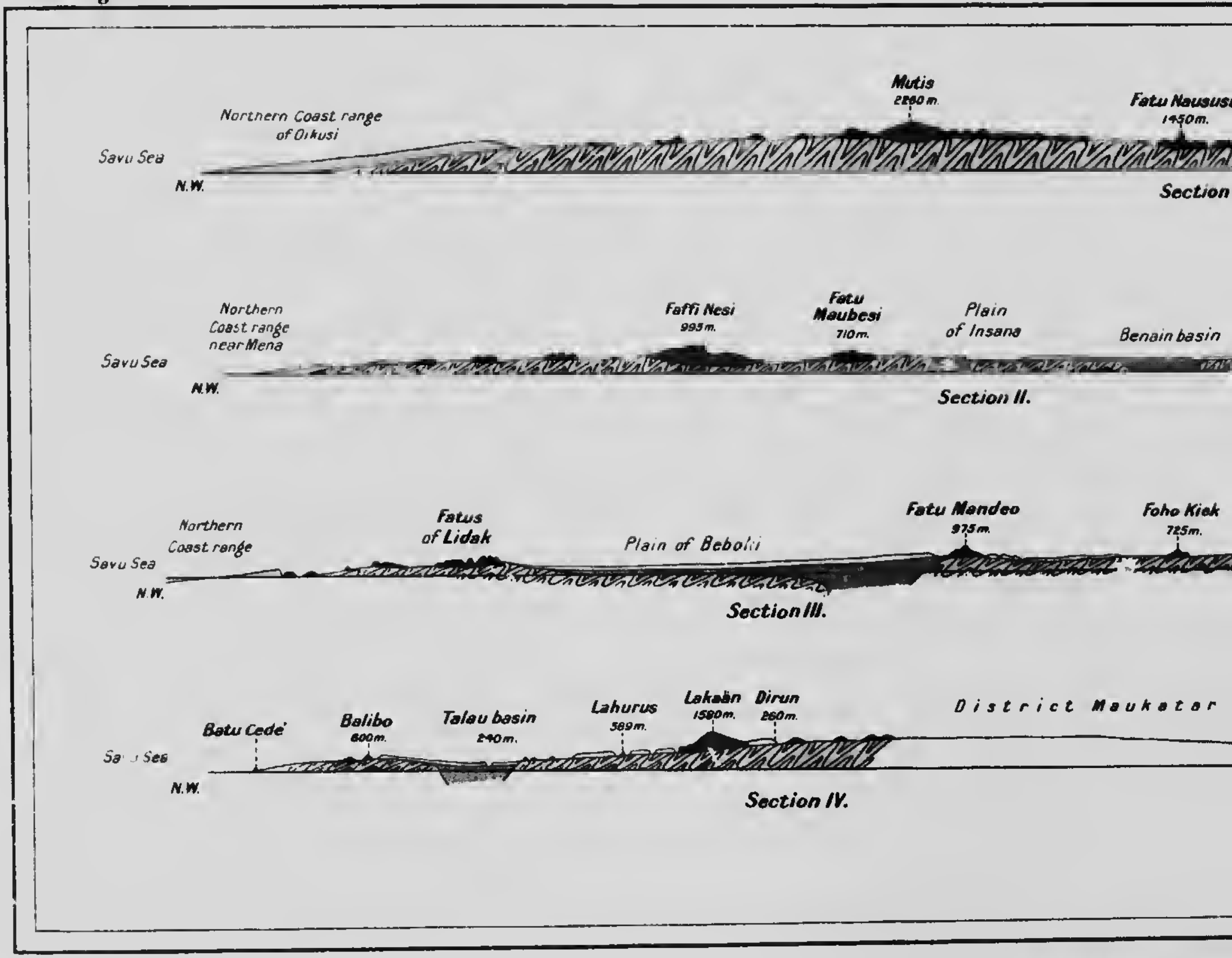
T. W. VAUGHAN (Washington) remarked that certain tectonic features of the West Indies were strikingly similar to some of those described by Professor MOLENGRAAFF for the East Indian regions. He called attention to the wide, flat plateau of the Great Bahama bank which lies east of the Tongue of the Ocean and the rapid drop from the surface of this plateau to the level of the bottom of the Tongue of the Ocean, 1,000 fathoms in depth. Exuma Sound, 1,000 fathoms deep, lies eastward of the shoal on the east side of the Tongue of the Ocean. The relations of the shoals and the deep bays and sounds of the Bahamas were, in the opinion of the speaker, probably due to block-faulting. The presence of a depth of over 1,000 fathoms off the north coast of the western part of Cuba paralleling the Organos mountains, and of a depth of 3,000 fathoms off the south side of the east part of the same island and paralleling the Sierra Maestra were mentioned as instances of the reciprocal relations of oceanic depressions and orogenic uplift.

G. STEINMANN (Bonn) called attention to the existence in the island of Timor of several very characteristic features of alpine structure and composition, viz., the diversity of facies of the Mesozoic formations, the deep-sea deposits and the contemporaneous ultrabasic eruptives. It seemed evident that the Timor range belonged to the alpine mountain type rather than the Cordilleran.



Preliminary geological Sketch map of the
Central Portion of the Island of Timor.
Malay Archipelago.

G. A. F. Molengraaff



Diagrammatic Secti

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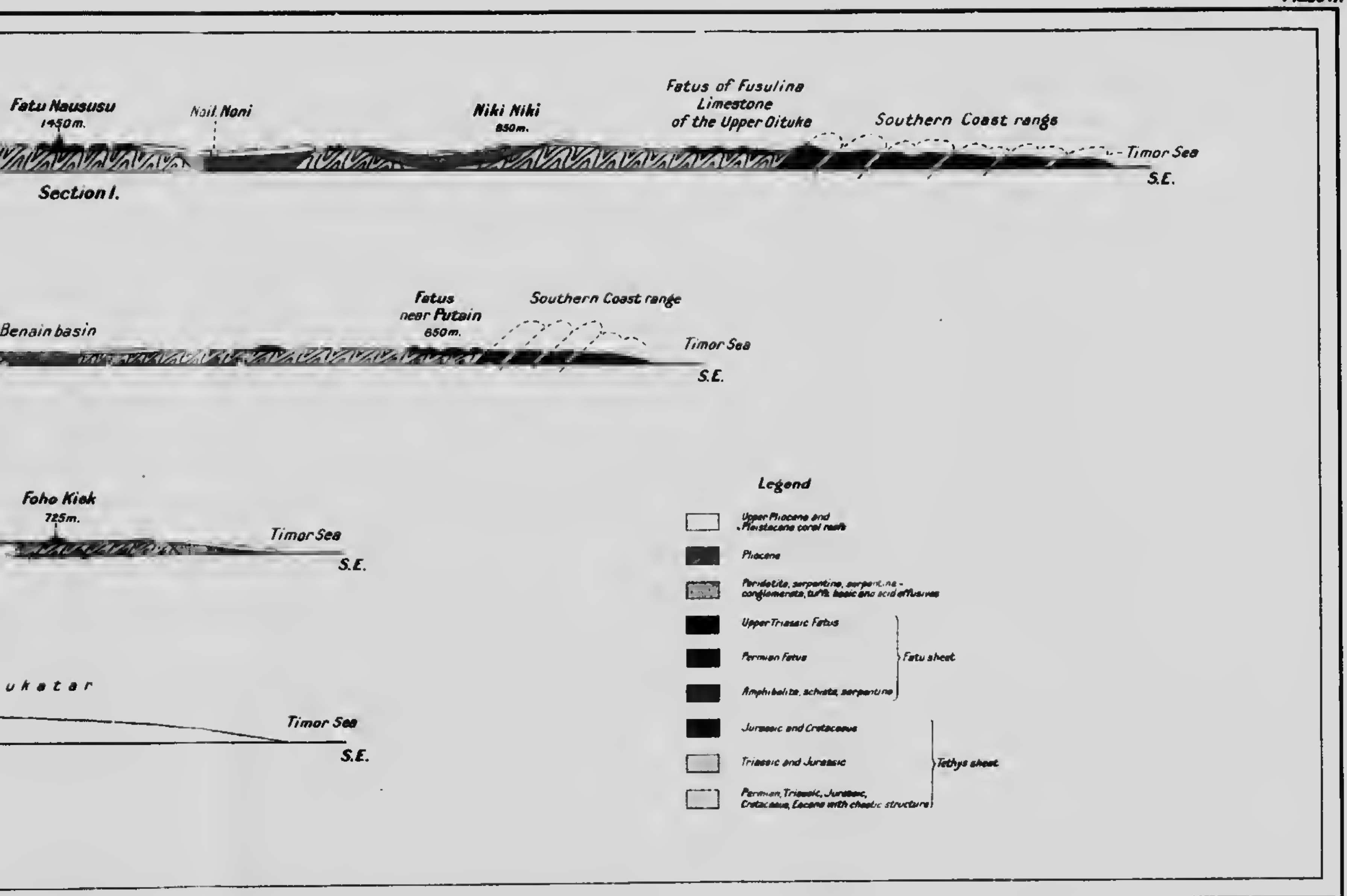


...atic Sections across the Island of Timor.

Longitudinal and Vertical scale.

5 10 15 Km.

LA GÉOLOGIE DU MAROC.

PAR

LOUIS GENTIL,

Professeur à l'Université de Paris.

M. LOUIS GENTIL présente au Congrès une carte géologique du Maroc au 1:2,500,000e qu'il a dressée pour servir à la carte du monde au 1:5,000,000e, et il expose, en s'aidant de ce document, les grands traits de la structure de ce pays du Nord-Ouest africain.

Le Maroc est traversé de long en large par une grande chaîne, l'Atlas, et il est borné au Nord par le Rif, qui ferme la Méditerranée occidentale. On comprend dans l'Atlas, le *Haut-Atlas*, d'où se détache l'*Anti-Atlas*, et le *Moyen Atlas*, tandis que le *Rif* paraît former une chaîne indépendante.

Les travaux des géologues qui ont parcouru le Maroc, notamment ceux de FLAMAND, LEMONIER, BRIVES et GENTIL, montrent que la série stratigraphique y est assez complète; terrains paléozoïques au complet, terrains jurassiques, crétacés, eocènes, néogènes. Les premiers affleurent, surtout dans le Rif et le Haut Atlas occidental; le Néogène marin forme une bordure importante dans le Maroc occidental et le Néogène continental s'étend sur les vastes surfaces dans les régions sahariennes. Des masses cristallines, surtout granitiques ou métamorphiques, forment des îlots importants dans les diverses chaînes.

Au point de vue tectonique, il est d'abord remarquable de constater que le Haut Atlas marocain—qui fait suite à la chaîne saharienne—a la structure du Jura français. Il s'en distingue seulement par des altitudes élevées qui peuvent dépasser 4,200 mètres.

M. GENTIL a pu se rendre compte que la grande chaîne s'incline, par un abaissement d'axe de ses plis, vers le rivage atlantique, pour s'enfoncer sous les eaux de l'océan et se relever aux Iles Canaries. Ainsi se trouve vérifiée la continuité de la grande chaîne alpine, par les Canaries et les Antilles, avec les Montagnes Rocheuses, et par l'Alaska avec l'Himalaya et le Caucase.

L'Anti-Atlas doit être considéré comme résultant d'une virgation des plis du Haut-Atlas; les deux chaînes encadrent la grande plaine du Sous.

La structure du Moyen Atlas demeure obscure par suite d'explorations insuffisantes, mais M. GENTIL a constaté, dans la vallée de la Moulouya, que les plis de cette chaîne se continuent, par le massif des Beni Snassen, avec ceux du Tell algérien, caractérisé par des plissements alpins.

Au nord du Haut Atlas occidental et à l'ouest du Moyen Atlas, s'étend une région plate, formée d'une série de couches horizontales secondaires ou tertiaires. Ces couches reposent sur les débris d'une ancienne chaîne carbonifère (hercynienne) complètement arasée à l'époque permienne et ainsi transformée en pénéplaine.

Les couches secondaires et tertiaires apparaissent sous la forme de plateaux plus ou moins étendus, rappelant ainsi fidèlement la structure du plateau central espagnol ou Meseta ibérique. Pour ces raisons, M. GENTIL désigne cette région africaine sous le nom de *Meseta marocaine*.

Le rôle orogénique de cette Meseta semblerait, d'après l'allure non plissée des couches secondaires et tertiaires qui la recouvrent, avoir été passif depuis la fin des temps primaires; mais l'auteur est porté à croire, d'après ses dernières observations, que la Meseta marocaine a largement contribué, par un mouvement de déplacement vers le sud,—ou plutôt, par un mouvement de bascule,—à plisser les sédiments de l'Atlas. Ceux-ci ont été ainsi resserrés, comprimés entre la Meseta marocaine et le plateau saharien, qui offre identiquement la même structure et aurait joué le rôle de bouclier durant les périodes secondaires et tertiaires. L'auteur arrive même à expliquer les hautes altitudes de l'Atlas, malgré la structure simple, jurassienne.

La constitution géologique du Rif demeure très obscure. M. GENTIL n'a pu aborder cette chaîne qu'à ses deux extrémités. Dans l'est, il lui a semblé qu'elle se séparait complètement du Tell algérien et du Moyen Atlas. Dans l'ouest, l'auteur a pu confirmer l'idée d'EDUARD SUESS de la continuité des plis du Rif et de la Cordillère bétique à travers le détroit de Gibraltar. Enfin au Sud, le Rif est séparé du Moyen Atlas par les dépôts miocènes.

Après avoir confirmé de façon définitive l'idée de MUNIER CHALMAS,—basée sur les observations de MARCEL BERTRAND en Andalousie,—que l'ouverture du détroit de Gibraltar est assez récente, datant du début du Pliocène, M. GENTIL envisage la question d'une ancienne communication entre la Méditerranée et l'océan Atlantique à l'époque néogène.

On sait que ces deux mers ont été reliées, au début du Miocène, par un détroit qui existait au nord de la chaîne bétique; le détroit andalou de Toi   ouev ou *détroit Nord-Bétique* d'EDUARD SUESS. Mais, comme cette communication était déjà fermée au milieu de l'époque miocène, il fallait qu'il y eut un autre chenal reliant, à l'époque du Miocène supérieur, l'océan Atlantique et la Méditerranée néogènes.

M. LOUIS GENTIL a pu en retrouver les traces dans ce qu'il appelle le *détroit Sud-Rifain*. Cette communication reliait le nord de l'Algérie au Maroc occidental par les emplacements actuels de Taza et de Fez, et l'auteur montre qu'il y a eu comme un balancement entre les trois détroits néogènes le détroit Sud-Rifain s'ouvrant dès la fermeture du détroit Nord-Bétique et la communication actuelle du détroit de Gibraltar se faisant,—par un effondrement des plissements du Rif et de la Cordillère bétique entre les deux colonnes d'Hercule,—dès la fermeture du détroit Sud-Rifain.

Enfin, M. LOUIS GENTIL appelle l'attention de ses confrères sur les richesses naturelles du Maroc avec ses zones minéralisées encore très mal connues ses grandes forêts de cèdres, d'arganiers et surtout de chênes-liège. Mai l'avenir du Maroc est entièrement dû à la richesse de ses sols. Le Maro occidental surtout, offre des terres humifères désignées sous les noms de *tirs* et de *harmi* par les indigènes et que l'auteur considère comme résultant d'une décalcification des terrains crétacés ou néogènes, avec accumulation de débris organiques d'une vigoureuse végétation herbacée et annuelle. Ces terres sont comparables, par leur fertilité, aux tchernoziens de la Russie méridionale.

DISCUSSION.

H. F. REID (Baltimore): The theory of Archdeacon Pratt, first given between 1850 and 1860, that the quantity of material in each section of the earth is the same, whether the section comprises mountains, plains or oceans, has been confirmed by the work of others and finally by Hayford and Bowie of the U. S. Coast and Geodetic Survey, by Helmert of the Prussian Geodetic Survey and by Hecker and Nansen's observations over the oceans. And this theory forbids the assumption that matter can be accumulated in any region and thus form a mountain range, and requires as stated by Major Dutton, that elevations be explained by expansion of the underlying material and depression by contractions of this material.

ON THE OLD RED SANDSTONE SERIES OF NORTH-WESTERN SPITZBERGEN.

BY

OLAF HOLTEDAHL,

University of Christiania.

I should like to give the Congress an account of the more important general results of the geological investigations that the Norwegian expeditions of the last four summers have conducted in northwestern Spitzbergen through Universitäts-stipendiat HOEL and myself, but time does not permit it. I shall therefore restrict myself to one special subject, viz., the highly interesting Old Red system of the area, a series of rocks that, in proportion to its great thickness and distribution, has been hitherto the least known of the many formations of Spitzbergen. It is now hoped that some of the chief features of this enormous sequence of strata are known, though to work the system out in detail would require years of unbroken study.

Instead of describing the various facts about the Devonic system of Spitzbergen, which were previously known through the Swedish investigations, I shall only mention the splendid book, "*Beiträge zur Geologie der Bären Insel, Spitzbergens and des König-Karls-Landes,*" published by Professor NATHORST in 1910,[1] wherein the details are given. It will suffice to say that the stratigraphical as well as the paleontological observations were very few and scattered, and that the thickness of the system was thought to be only a small part of what we have now found it to be.

In Spitzbergen the Old Red Sandstone series rests upon the so called Heclahook system, consisting of a great thickness of more or less crystalline sediments, phyllites, mica schists, quartzites, and limestones, which have been and are still regarded as equivalent to the Ordovicic and Siluric series of Scandinavia. On Bear island, half-way between Spitzbergen and Norway, high Ordovicic fossils are found in similar Hecłahook rocks, indicating this age for a part of the system.

Younger than these sediments and contemporaneous with those great folding processes that altered the original deposits to crushed and crystalline rocks, are huge masses of intrusive granites and gneisses, making up the northwestern corner of West Spitzbergen. These were formerly believed to represent an Archæan system.

These strong crustal movements have naturally been considered as a northern phase of the Caledonian crust movements of Scotland and the Scandinavian peninsula and, therefore, were regarded as having taken place

[1] Bulletin of the Geological Institution of Upsala, Vol. X.

at the end of Siluric time. However, we have learned from our studies of the younger rocks that the chief movements probably were somewhat earlier, for we find resting on the remnants of the folded mountains a series of coarse clastic rocks containing fishes that seem to be of Siluric time. These are probably contemporaneous with the Downtonian of Great Britain and with the Red Sandstone series of the Kristiania area in Norway, where in the last few years a fauna of fishes and eurypterids indicating youngest Siluric age has been found.

Before the oldest known of the Old Red sediments of Spitzbergen were deposited, erosion worked far down into this folded range, into the zone of mica schist and intrusive granitic masses.

RED BAY SERIES.

An enormous series of conglomerates that rests on the Heclahook schists, crystalline limestones and granites constitutes the basal number of the overlying clastic series. These conglomerates are chiefly of continental origin and were laid down in troughs in the still not base-levelled land surface. The contact between the Heclahook and the conglomerate is usually marked by huge sharp-edged pieces of loose rock that have not been moved at all, but represent the fractured older formation. Higher up the conglomeratic materials become smaller, more rounded and exclusively quartzose. This fine-pebbled conglomerate, which mostly shows very little marked bedding, has the deep red colour of iron oxide. The thickness of the conglomerate is 500–600 m., in some places probably more.

In the Red Bay region, these basal beds are followed by a yellowish white, coarse, moderately crossbedded and unfossiliferous sandstone, 100–200 m. thick, indicating the flattening out of the land forms. Resting conformably on this sandstone are the, as yet, oldest known fossiliferous beds of Spitzbergen, a series of hitherto totally unknown gray-green, in some layers reddish, sandstone, rich in mica and with a known thickness of at least 2,000 m. Crossbedding is common but generally not very coarse. Certain layers throughout the whole thickness, and especially in the red, often limy beds, contain a rich and well preserved fauna, consisting of placoderm fishes, belonging to the genera *Pteraspis*, *Palæaspis*, *Cephalaspis* and some new genera. About 35 species are identified. According to Prof. J. Kiær of the University of Kristiania, who is working out our material of fishes from the sandstone series, they probably indicate highest Siluric time. In addition some species of lamellibranchs are found, represented by a great number of individuals. In two horizons are found badly preserved Ostracods, *Leperditia* or *Isochilina*, of medium size. We have collected fossils systematically from more than twenty horizons, representing a thickness of about 1,000 m.

After the deposition of the Red Bay series, some orogenic movements—block faulting—probably took place, for the beds are somewhat disturbed and in places the whole series was eroded away before the next series was deposited.

WOOD BAY SERIES.

In this group come the mica-rich, red and chocolate coloured sandstone and shales that cover a great part of northern Spitzbergen, though not nearly as much as was previously assumed. The rocks are mostly rather regularly bedded and very frequently ripple-marked. We collected fish faunas in numerous horizons in this series, chiefly of *Pteraspis*, *Cephalaspis* and *Acanthaspis*, and indicating a Lower Devonic age. These fish remains are found only in certain layers, but are there abundant, though generally with the plates isolated as if they had been transported for some distance. Besides the fishes, ostracods and plant remains are found in the Wood Bay series. The ostracods, a big Leperditia and an Isochilina, are very numerous in certain limy layers.

The thickness of the Wood Bay series, as this group may aptly be called, is about 3,000 m.

GREY HOEK SERIES.

Higher in the sections follow 200 metres of transitional rocks, and these are succeeded by the grey slates of the Grey Hoek peninsula, between Wood bay and Wijde bay. This is a homogeneous sequence of sediments, with a fauna consisting of a vast number of individuals belonging to but a few species of lamellibranchs, and a gastropod described twelve years ago by Professor E. KAYSER from a Swedish collection from Grey Hoek point. These same forms, amongothers *Avicula*, *Myalina* and *Palaeonodonta*, are found throughout the whole thickness of perhaps 2.000 m., but no other fossil except some few fish and plant remains.

WIJDE BAY SERIES.

The Grey Hoek series is overlain without marked unconformity by the uppermost known Devonic group, present chiefly along the western side of Wijde bay, and consisting of grey sandstones and slates with Upper Devonic fishes, *Holoptychius*-like forms, *Psammosteus*, etc. In a few horizons are found a big Isochilina, and a nuculoid lamellibranch, both represented by a great number of individuals and building up limy layers. In the Ice Fjord region, Professor NATHORST has also found fishes, plant remains and an *Estheria*, undoubtedly belonging to this series.

The total thickness of the Grey Hoek and the Wijde bay series is estimated to be about 4,000 m. The rocks are folded considerably so that an exact figure can only be obtained by very detailed field work.

It will be seen that the Downtonic-Devonic beds of Spitzbergen have an enormous thickness, amounting to about 10,000 m. We have here, in fact, a very interesting parallel to the famous Scottish Old Red system. We have:

In Spitzbergen.	*In Scotland.*
Wijde Bay series (Upper Devonic).	Upper Old Red.
Grey Hoek series (age unknown).	Middle Old Red (Orcadian).
Wood Bay series (Lower Devonic).	Lower Old Red (Caledonian).
Red Bay series (highest Siluric).	Downtonic.

For want of guide fossils in the Grey Hoek series, there is as yet no proof of its contemporaneity with the Middle Old Red. It is, at any rate, an interesting feature of likeness that both groups typically show more fine, clastic, argillaceous material than the older and younger series, and a grey colour, probably indicative of a more pluvial climate.

A point of difference between the two areas is that in Spitzbergen conditions from Lower to Upper Devonic time were more stable, with a less interrupted deposition in one great basin, while in Scotland great tectonic disturbances took place during this period, causing a strong denudation and the formation of more isolated troughs of deposition. Another and very interesting difference is indicated by the occurrence of fossils of distinctly marine type, such as some of the lamellibranchs and big ostracods, in the Spitzbergen series. It looks as if the Spitzbergen basin was at no time during the periods of deposition far beyond the reach of the sea. We probably shall come nearest the truth by imagining a widespread delta deposition, with partly fresh, partly brackish water that periodically covered great areas of the flat delta land. The Grey Hoek series, with its homogeneous shale deposits and its small fauna of lamellibranchs, was probably laid down in a large lagoon-like body of water, to which the scanty fish remains were carried down by rivers.

It is as yet impossible to tell from lithological observation from what direction the immense amount of clastic material making up the different series was carried. The Hecla-hook rocks exposed in the surrounding regions generally show very similar characters in different directions. Yet it seems very probable, on general geologic grounds, that an open sea existed to the north and east during the whole period, and a high land in the west and south.

In the first place, we know from the collections of the second "Fram" expedition that the open sea spread over the Ellesmereland region during at least the greater part of Devonic time. In Greenland, Scotland and Norway we know only of continental conditions during Devonic time, while from Nova Zembla and the north of Russia, marine beds of the same age exist. The Devonic coarse conglomerate and sandstone beds of western Norway show directly in their structure that they were deposited on a surface dipping to the southeast, an indication of high land in the opposite direction.

Secondly, the same view comes naturally from consideration of the Siluric-Devonic geology of northwestern Europe. We know from investigations, both in Great Britain and in the Scandinavian countries, that in general in Ordovicic and Siluric time a land of great extent lay to the northwest, that is, on the Atlantic side. The influence of this continent is very strongly marked in late Siluric time. In Scotland and the north of England, we find immense masses of coarse clastic material coming from the land, and in Norway the Siluric limestones of the Kristiania area are replaced to the northwest by clastic material that was derived from the west. We are able to see how the western upheaval gradually spread toward the southeast, accompanied by a deposition of red sandstones along the southeastern border. In the north-south belt of unmetamorphosed sediments in southeastern Norway—the Kristiania area—we observe that the marine deposition is replaced to the north by the barren sandstone in late Wenlock time; while to the south a similar change first appears at the beginning of Downtonian time, where the marine beds are followed by fish-bearing red sandstones.

If we now consider the intimate relation that no doubt exists between the Caledonian folding throughout Scotland, Scandinavia and Spitzbergen, and the distribution of the red sandstones, it seems very probable that also in the northern part of the folded area the high land was on the Atlantic side.

It seems very probable, from the conditions in Bear island, where the only sediments between the Heclahook and Upper Carboniferous are the high Devonic Ursa sandstone, a continental deposit with finely preserved plants, that there was no sea to the south of Spitzbergen. It is possible that some of the Spitzbergen beds, *i.e.*, the Grey Hoek series, were only deposited near the present north coast, as no trace of that group seems to exist to the south, near Ice Fjord. Yet it may be that the beds were removed by later erosion, during local uplifts which are known to have taken place before the oldest Carboniferous sediments were deposited.

During Lower Carbonic time continental conditions still prevailed in Spitzbergen and Bear island, while to the southeast in Nova Zembla, marine rocks of that age are known. The plant-bearing, mostly white or yellowish coloured Lower Carbonic sandstones of northwestern Spitzbergen are found to have a very great thickness, 1,200 to 1,300 m., and yet the base was not seen. New local uplifts with enormous erosion followed in late Lower Carbonic time. A good idea of the amount of the Palæozoic denudation in these regions is given by the fact that, at one place in the central part of the northwestern corner, the series between the Heclahook and the marine Upper Carboniferous is represented by only about 200 metres of sediment, consisting of sandstones of the Wood Bay series. Even if we assume that at this particular place the *whole* thickness of Old Red beds found at the north coast was originally not deposited it is beyond doubt that several thousands of metres were present but were removed in Carbonic time.

An interesting fact regarding the uplifts and periods of erosion is that, in spite of this immense destruction, the surface on which the oldest marine beds were deposited was a complete plain, without notable irregularity for tens of miles. Over great areas the marine Upper Carbonic limestones rest upon the Lower Devonic sandstone with absolute conformity.

By finding in several places in the basal marine beds fossils indicating the age of the Moscow horizon (Middle Carboniferous of the Russian standard), we have fixed the time of the great trangression of the sea in the Spitzbergen area, and have proved that it was contemporaneous with that of Bear Island, of parts of Timan and Ural in Russia, areas in Asia, etc. One sees how the sea in the north at once covered the whole immense area of perfectly flat land, and how reef-like coral masses began to grow on the basal pebble layer, and how, during a slow and regular subsidence in Upper Carbonic and Permo-Carbonic time, there were laid down about 1,000 metres of marine beds, [illegible]stone and cherty material.

FORTY-FIRST PARALLEL SURVEY OF ARGENTINA.

BY

BAILEY WILLIS,

United States Geological Survey, Washington, D.C.

With a map.

ORGANIZATION.

The Forty-First Parallel survey of South America is officially known as the Comisión de Estudios Hidrológicos del Ministério de Obras Públicas, de la Republica Argentina. It was organized in January, 1911, under the Minister of Public Works, Don Ezequiel Ramos-Mexia, to further his purpose of developing the national territories of Argentina by means of railway building. For some years previous to 1911 the Minister had carried on railway construction in the southern territories of Rio Negro, Chubut, and Santa Cruz, into which Patagonia had been divided, and also in the northern territories of the Chaco and Formosa. As the regions to be penetrated are to a great extent semi-arid and water is scarce or of poor quality, serious difficulties had been met both in construction and in the operation of that part of the lines which had been built. It was with the hope that geologic investigation would result in the discovery of sufficient water supplies of good quality that the Minister called upon the Geological Survey of the United States for assistance, and the preliminary organization of the Comisión was designed to carry on topographic and geologic surveys which should solve the problem of water supplies. When, later, it was found that the region to which the studies were directed was of such a structure that artesian waters could not accumulate, the attention of the Comisión was directed to the solution of the problem by means of engineering works for the storage of available surface waters and of canals to conduct them to points where they might be utilized. By degrees the surveys were extended to become a general study of the natural resources of the northern part of Patagonia. It became necessary to make general topographic surveys as well as detailed location surveys to determine the route of the railroad. The Cordillera of the Andes was explored to discover routes of communication, to locate centres of settlement, and to estimate resources in water-powers, forests, etc.; and finally the lands of the region surveyed were classified according to their future uses for agriculture, grazing or forestry. Thus the survey has been intimately related to a policy of railroad development and the problems presented to it have been essentially economic; but, as the Minister was a broad-minded, far-seeing statesman, he realized that the economic study could not have its highest value unless it were founded upon scientific investigation of the topography, geology, climate and resources of the region. He therefore gave his unqualified support to the scientific work in so far as it could be shown to have a relation to the purposes of the law which controlled the survey's expenses. Certain problems of scientific interest were necessarily excluded because the expenses of the investigation could not legally be paid from the appropriations which supported the work. Our studies, therefore, can do little more than to indicate the broader geologic relations which we have not been able adequately to investigate.[1]

PROGRESS OF THE WORK.

The district assigned to the Estudios Hidrológicos for its initial operations lies in northern Patagonia along the forty-first parallel of south latitude, between San Antonio on the Atlantic coast and Lago Nahuel Huapi in the Cordillera of the Andes. The distance from one point to the other by the projected railway is 626 kilometres.

The surveys began near San Antonio in March, 1911, and were extended westward during the winter season until October of that year. They were then transferred to the Andes for the summer months, in order to explore for a railway pass by which the Patagonian line could be extended to Valdivia on the Pacific coast. The various parties were occupied in pertinent studies during the summer of 1912. In the winter of that year they returned to the region of the Pampas where topographic work was carried on, while the geologists worked up their results. In the spring the force was again transferred to the Andes for the purpose of making surveys for branch

[1] The survey was officially organized as the Comisión de Estudios Hidrológicos. The personnel at first was: Bailey Willis, Geologist, U. S. Geological Survey, Director; Emilio E. Frey (Argentine), Assistant Director and Topographer; C. L. Nelson and W. B. Lewis (U. S. Geological Survey), Topographers; J. R. Pemberton (Stanford University), Geologist; C. W. Washburne (U. S. Geological Survey), Geologist; W. D. Jones (University of Chicago), Economic Geographer; Otto Luginbuehl, Walter Graenacher, and Walter Eschmann (Switzerland), Assistant Topographers. In course of the work Messrs. Eschmann and Graenacher resigned. C. F. Eberly (U. S. Geological Survey), was appointed Topographer to replace Graenacher. J. S. Mercer (Chicago), and Otto Schneider (New Zealand), were appointed Assistant Topographers. D. L. Raeburn, Civil Engineer, and J. G. Morgan, Assistant Engineer, were added to the corps in 1912-13 to survey a railway location. Ricardo Dowdall, R. M. Rodriguez (Argentine), and R. M. Hatch (University of Wisconsin), served successively as secretaries in charge of administration and accounts.

The original contract took effect January 21, 1911, and was to run for two years, but was extended by mutual agreement to December 31, 1913, with the understanding that the field work in hand should be finished, and the manuscript of the reports completed by that date. In July, 1913, the Minister, Ramos-Mexia, resigned, but the prorogation of the contract to the end of the year has been confirmed by his successor, Ministro Carlos Meyer-Pellegrini.

The field work was prosecuted continually and vigorously until April, 1913, the operations being carried on in different districts according to the season. With the beginning of the winter season of this year the force has been reduced by the expiration of the contracts with the majority of the American members, who have returned to the United States. Messrs. Eberly, Luginbuehl, Mercer, Schneider and Hatch continue in the field under the direction of Señor Frey to complete the topographic surveys.

railway lines north and south of Lago Nahuel Huapi, and of studying that section of the Cordillera which might be tributary to the transcontinental railway. This work extended from San Martin de los Andes in the north to Rio Corcovado in the south, or from latitude 39° 40′ to 43° 40′, in the Cordillera. It was brought to a close in April, 1913, by the inclemency of the winter season, and the field work was again transferred to the Pampas. Although further construction of the railways is temporarily checked, the Administration has made a liberal allotment for the completion and publication of the scientific and economic data, and the members of the Comisiòn are now engaged in preparing final reports. These are to cover the geological reconnaissance, the investigation of the resources of the Pampas and the Andes, and the conclusions reached in regard to the capacity of those regions for settlement; and they are to be accompanied by topographic and geologic maps, as well as by others showing the classification of the lands throughout the zones covered by the surveys.

The zone of accurate topographic surveys executed by Messrs. FREY, NELSON, LEWIS, PEMBERTON, GRAENACHER and LUGINBUEHL extends from the Atlantic to the Chilean boundary in the Andes. It is controlled by triangulation and a well-checked line of levels 750 kilometres long and covers an area of 16 000 square kilometres. The geologic and land classification reconnaissance surveys cover the same area, and also extend in the Cordillera of the Andes over 31,000 square kilometres more. In this latter area they are based on the reconnaissance topographic maps prepared under the direction of Dr. F. P. MORENO by the Argentine staff of the Comisión de Limites prior to 1902. Messrs. JONES, PEMBERTON, WASHBURNE and WILLIS executed the geologic surveys and classified the lands.

During the season of 1912-13 the route of the railroad, which is to connect San Antonio with Lago Nahuel Huapi, was surveyed across the high plateaus of the Pampas by Messrs. D. L. REABURN and J. G. MORGAN, while Messrs. NELSON, LEWIS, EBERLY and MERCER surveyed railway routes north and south from Lago Nahuel Huapi, within the Cordillera.

CHARACTERISTICS OF THE REGION SURVEYED.

The region surveyed falls broadly into two very distinct physiographic provinces: one is that of the Pampas of northern Patagonia, corresponding with the treeless plains and plateaus which extend from the Atlantic ocean to the eastern ranges of the Andes; the other is that of the Cordillera of the Andes, which is in great part heavily forested and which harbours many beautiful lakes. The former is semi-arid and is often desert-like; the latter has an abundant rainfall and by its climate, healthfulness and resources is destined to become the seat of a dense population. We may briefly describe these two distinct provinces.

PAMPAS OF NORTHERN PATAGONIA.

The Pampa region falls into four districts, which, enumerated in their order from the Atlantic westward are: the coastal belt, the district of interior basins, the high plateaus and the pre-Andean depression.

The Coastal Belt.

The coastal belt at San Antonio itself is low; the land scarcely rises from the bay which there indents the coast, and the strong tides of 8 to 12 metres penetrate beyond the head of the bay far into the plain; but both northward and southward the coast extends as an upland bordered by sea cliffs, and reaches back from the coast as a rising plain. Going westward from San Antonio on the railroad one ascends gradually in 35 kilometres to a height of about 80 metres, and there encounters a steeper slope up to an altitude of 170 metres. As seen from below the slope appears as a range of hills surrounding the lowland of San Antonio, but from above it is recognized as a steep connecting the lower and the higher planes. It is one of those surfaces which are common throughout the warped plateaus of northern Patagonia and which correspond to a flexure rather than to an erosion scarp. The lowland about San Antonio is a depressed area, or an area which has not shared in the general elevation of the surrounding region. It is partly submerged beneath the sea. There are many such depressions in northern Patagonia, some of them of great extent and without outlets. They will be referred to hereafter under the descriptive Spanish name of bajos.

The high flat to which the railroad ascends at 170 metres above sea is a very extensive feature of the coastal plain. It is a nearly flat surface, yet is undulated to such a degree that a horseman soon disappears beyond some rising swell, and there are innumerable little basins which form transient ponds during the rainy season. These inequalities are due to wind erosion. Where the winds have worked out a harder layer in the sandy gravels of the plain there may be an angular facet in the corner of some low hill. Otherwise the country is featureless. It is covered with a growth of desert shrubs of many varieties and with grasses which afford excellent pasture.

The gravels which constitute the plain have not yielded any fossils, but are provisionally assigned to the later Tertiary, as they overlie marine sediments which contain a fauna of Patagonian (early Tertiary) affinities.

District of Interior Basins.

West of the coastal belt the railroad enters a great bajo or depression, which, as a whole, we may call the Bajo de Valcheta, that being the name of the principal stream tributary to it and of the town which has been established where the railroad crosses the brook. From a maximum altitude of 220 metres on the highest portion of the plain, the surface descends in the Bajo de Valcheta to a minimum altitude of 83 metres above the sea. The depression is in the form of a long lunette, the curve being convex toward the northeast. A line between the points extends from northwest to southeast and has a length of about 100 kilometres.

Southwest of the bajo is a plateau capped by heavy lava flows, and from this plateau several streams run northeastward into the bajo, where they are lost in gravel beds or form salt lakes and evaporate.

It is of interest to consider for a moment the character of these streams, whose appearance in a desert landscape is somewhat extraordinary. Where we would expect them to be dry during much of the year, they flow with a remarkably constant volume, and their valleys are characterized by extensive swamps, in striking contrast to the arid slopes that border them. The Arroyo Valcheta is typical. It rises in three large springs which issue from beneath the lava plateau near the junction of the overlying lavas with an underlying impervious bed, and while the springs are the visible source of the river, they are in fact but the point of issue of underground streams which accumulate in the lavas. Ascending to the surface of the lava plateau, one finds it exceedingly irregular and without well defined drainage channels. At the season of rains or of melting snow it is covered with ponds whose waters sink into the crevices in the deep lava mass. The surface is high, 900 to 1,200 metres or more above sea, and above it rise volcanic peaks, of which the highest, Somuncurá, reaches an altitude of 1,800 metres. It therefore receives a larger amount of precipitation, especially in the form of winter snow, than the adjacent lowlands, and of this precipitation a very large proportion seeps into the mass of broken and porous rocks, since both run-off and evaporation are limited. Thus the lava field is a great reservoir, and the seemingly worthless plateaus, too stony and too high for cultivation, are in fact the sources of those waters upon which the population of the region must depend.

On leaving the Bajo de Valcheta some 200 kilometres west of San Antonio the railroad rises to the surface of a lava plateau at Corral Chico, 490 metres above sea, and continues westward for some distance over its uneven surface. The line then enters a valley among hills of red rhyolite and for a long distance traces a course among stony buttes, beneath escarpments of lava, yet past valleys where alfalfa is raised by irrigation from springs and the herds of an English estancia graze on the native pasture grasses. The topography of this rhyolite belt is apparently very old and in part resurrected, as early Tertiary sediments are laid down on the basal complex, of which the rhyolites form a very striking element. Rhyolite is here used as a comprehensive term to designate a variety of rocks, ranging from granite to rhyolite, which occur in enormous masses in this region. One of the interesting geologic problems which we have not yet been able to investigate is that of the relations between the granites, the rhyolites and the intermediate varieties, which here occur in very unusual volume and beautifully exposed.

Still threading its way westward, the railway line arrives in the valley of the Arroyo Maquinchao about 380 kilometres west of San Antonio. The elevation is 900 metres above sea. The arroyo rises in a group of volcanic mountains 50 to 75 miles south of the railroad, then flows northwestward to a large lake without outlet, known as Lago Carilaufquen. The Maquinchao valley is the site of an English estancia of 600,000 acres extent, and will eventually be settled by a community which will utilize the waters of the stream to irrigate the rich valley lands. Situated halfway between the Atlantic and the Cordillera, the district is intermediate between the rains which pass eastward over the Cordillera and those which swing in from the Atlantic over the coastal belt. It therefore receives a minimum precipitation and presents the nearest approach to a desert region of any part of the zone from the Atlantic to the Cordillera. The rainfall varies periodically. In 1898-99 it was very heavy and all the shallow basins of the region became lakes, while the lowlands were converted into swamps. Recent years have been marked by long periods without rain, and it is probable that the cycle of climatic variation has touched the extreme of aridity. The range of precipitation is from 100 to 400 mm., more or less, and the long cycle of change involves many minor fluctuations of less intensity from year to year. These climatic conditions are characteristic of all of Patagonia.

Lago Carilaufquen, the basin in which Arroyo Maquinchao ends, receives the drainage of another stream, known as the Arroyo Güagüel-Niyeu, which flows from the west. This arroyo rises in the highest group of volcanic peaks of the region. Anecon Grande reaches 2,013 metres in altitude and equals the general elevation of the summits of the Andes in this latitude. It is an old and deeply eroded volcano, probably of middle or late Tertiary age.

The railway line extends from the Carilaufquen depression, which is surrounded by lava plateaus, westward up the valley of Güagüel-Niyeu to Huanuluan, an English estancia belonging to the Maquinchao property. It thus reaches the western limit of the interior basins and, crossing the divide west of Huanuluan, enters the watershed of the Rio Limay in longitude 70° W. of Greenwich. The valley of the Arroyo Güagüel-Niyeu, like that of the Maquinchao, is broad and flat, filled in with coarse gravels to an unknown depth, and covered with a fine æolian soil, which is so impervious that it forms swamps during the heavier rains. At Huanuluan, 100 kilometres west of Maquinchao or 500 kilometres west of the Atlantic, the altitude of the valley is between 900 and 1,000 metres above the sea, while the neighbouring plateaus rise to from 1,200 to 1,500 metres. The rainfall comes from the Cordillera and, owing probably to the immediate vicinity of the high peaks of Anecon Grande, is heavier than it is a short distance to the eastward. Huanuluan is, therefore, exceedingly well situated for sheep-raising as the valleys are not too high for winter grazing, the mountain slopes afford excellent conditions for summer pastures, and the rainfall is adequate to maintain a luxuriant growth of native grasses.

The drainage from the eastern side of Anecon Grande is still tributary by the valley of the Güagüel-Niyeu to the interior basin of Lago Carilaufquen, but in proceeding across the divide toward the north and west we leave the district of the interior basins and enter that of the high plateaus.

District of the High Plateaus.

The district of the high plateaus is a very extensive one in the western part of Rio Negro, with a general elevation of 1,000 to 1,200 metres, and rising locally to 1,600 metres above sea. The high plateau extends in a broad belt parallel to the Rio Limay and, southeast of that valley, from near the junction of the Limay and Neuquen southwest to the southern limit of the territory in latitude 42°, where it falls away toward the Rio Chubut. An Indian name which is sometimes attributed to a range of mountains, but which applies generally to this plateau region, is Huincul-Mapu. When interpreted it means the place or range with passes, and is very descriptive of the character of the plateau. It is a broad, elevated plain, surmounted by mountain peaks that are distributed singly or in groups over its surface, and is easily traversed in various directions by the many passes that lie between the hills. The plain is in part a plain of erosion cut upon metamorphosed rocks, granite or rhyolite, and in part corresponds with the surface of extensive lava flows. The hills in general present lower slopes of the basement complex, capped by a thin sequence of sedimentary strata surrounded by lavas. The springs of the region all issue from the bases of the lava summits and are rather limited in volume, as the catchment areas are usually small.

In Anecon Grande and its radiating spurs the character is somewhat different, as the greater elevation of the central peak makes it the source of streams which flow from it in all directions and which cut the plateau with deep canyons.

Northward from Anecon Grande flows the Cumallo, a tributary of the Limay, the various head branches of which drain all of the northern slope. From the southwest and southern sides flow various streams which are tributaries of the Rio Chico, a branch of the Chubut, and eastward the valleys descend to the Güagüel-Niyeu.

The geologic structure of the high plateaus being complicated and the topographic features being unequally developed, the region presents a great variety of aspects. It is dominated by the high volcanic peaks of Anecon Grande, El Arco, El Camelo, and others. The volcanics rest upon eroded surfaces of pre-Cretaceous rhyolites and descend into deep valleys cut in these older rocks. Tuffs and gravels of late Tertiary age have been deposited over the previously existing irregular surface of erosion, and the radiating streams superimposed upon these soft rocks have sunk broad valleys in the tuffs or have cut narrow canyons where they have come down upon spurs of the harder rocks beneath. Thus the valleys, though generally wide, narrow occasionally to mere gateways or to impassable gorges. The surface of the tuffs constitutes a flat plain, and though it is traversed by canyons from 150 to 200 metres deep, it looks continuous as one rides over it. The relief being thus rugged and the valleys thus difficult to follow, the location of a railroad line westward from Huanuluan in the direction of Lago Nahuel Huapi has proved a somewhat difficult task, but the American engineers who were called in by the Comisión de Estudios Hidrológicos have succeeded in solving the problem and locating a satisfactory line across the district.

Northwest of Anecon Grande, and separated from it by a low pass between the headwaters of the Arroyo Cumallo and those of the Rio Chico, is a high range composed largely of the old rhyolites. The summits attain altitudes of 1,400 to 1,500 metres and extend from north to south, dividi the valley of the Cumallo from that of the Arroyo Pileaniyeu, a tributary the Pichilenfu which runs northward to the Limay. The watershed of t Pileaniyeu may still be considered as part of the high plateau district, althou the plateau character has disappeared and the mass is represented only l the ranges of the old rocks which border the valley. The valley itself eroded to a depth of 400 or 500 metres below the mountain summits ar follows the line of an earlier erosion channel which was once filled wit Patagonian sediments and tuffs. It has also been the site of late Tertiar vulcanism, which has poured out small lava flows and has caused the in duration of some of the Patagonian sediments. It is a picturesque region varied in profile and in colour. In places the valley is a broad green meadow and again it narrows into short stretches of canyon. At one point near th English estancia of Pileaniyeu the indurated Patagonian sediments, varying from white through yellow to deep brown, form a high pinnacle, which th wind has carved into a shape that is fancifully compared with the head o Queen VICTORIA and is known through the region as La Figura. It is an isolated example of a type of erosion which is very common farther north on the Rio Colloncurá.

Southward beyond the headwaters of the Pileaniyeu, the plateau district slopes away to the canyon of the La Bayas. It is also limited toward the west by the long valley of the Pichileufu, which heads in the Cordillera of the Andes. Thus the plateau district is separated from the Andes by the depression which we may call pre-Andean.

Pre-Andean Depression.

The pre-Andean depression, which in this latitude is occupied by the Pichileufu, extends along the front of the range as a general feature of continental warping. It is not a continuous trough, since it has been filled in by deposits of tuffs, by lava flows, and by glacial formations, which in turn have been more or less eroded, according to their antiquity; yet it is sufficient to separate the district of the high plateaus from the Cordillera itself as elevations which are distinct from one another. It is desirable to note in passing that the high plateaus are not greatly inferior to the Cordillera itself in altitude, and that they constitute an uplift of similar orogenic character. Each is an elevation of a zone extending from north to south. The two zones are approximately parallel. They are both broad and plateau-like, and they are separated by a trough which has not shared equally in the movement of elevation. The trough has naturally become the site of river valleys and has been more or less filled, as well as more or less eroded, according to the local conditions. The pre-Andean depression may be traced upon any map which shows the headwaters of the Rio Limay and the Rio Chubut. Beginning at the north at latitude 39°, it is occupied by the Rio Alumine and the Collonenrá, which flow southward to the Rio Limay. Nearly at the same point the valley of the Pichileufu is tributary to the Limay, and w may follow it southward to near its head in the Andes where, at 1,200 metres above sea, we cross gravel plateaus of the earlier Glacial epoch to the head of the Arroyo Las Bayas. The Las Bayas flows eastward around the lava coulées that issued from Pico Quemado and here fill the pre-Andean depression. In latitude 41° 30′ rise several arroyos, of which the Norquinco is the principal one, and they, with the Rio Chico, take their courses in the pre-Andean depression southward to Fofocahuel. The Rio Tecka, flowing northward, joins the Rio Chico at Fofocahuel and the two form the volume of the Rio Chubut that flows eastward to the Atlantic. The Tecka occupies the pre-Andean depression from its source in the vicinity of latitude 44° 30′ northward. A study of the physiography shows that each of these streams (Aluminé, Colloncurá, Pichileufu, Rio Chico and Rio Tecka) existed in late Tertiary time, and that they occupy an orogenic depression which developed simultaneously with the uplifts of the Cordillera and of the high plateau district.

It would be an error to leave the impression that the pre-Andean depression is at the present time a wide valley. The rivers have sunk their channels in its original floor, and the Pichileufu flows in a canyon that is in some places bounded by rocky walls, in others skirted by gravel terraces. The mountain slopes rise 500 metres on each side of it and the mountains themselves are cut across by valleys and wind-gaps, which are occupied by moraines and bordered by outwash gravels of the early Glacial epoch. The scenery is, therefore, one of diversified profiles and varied aspects.

The pre-Andean depression may be said to branch, in the basin of Lago Nahuel Huapi, into the Cordillera itself. The elevation of the lake is but 767 metres above sea, and the Limay, taking its rise at the outlet, flows northeastward for a long distance in a canyon corresponding in course with the structural trough to where it joins the Collonenrá. Lago Nahuel Huapi occupies a basin which has been greatly deepened by glacial erosion and, corresponding with the former canyon of the headwaters of the Limay, extends some 60 miles northwest into the Cordillera. The railroad, which reaches the lake near its outlet and crosses the Limay at that point, is designed to extend along the north shore of Lago Nahuel Huapi and by way of tributary valleys northward to the basin of Lago Villarino. From this basin a branch may be extended westward to cross the Andes in the pass of the Cajon Negro at an elevation of 1,180 metres above sea, with a tunnel about one mile long through solid granite. The descent on the Chilean side is relatively steeper, but the line would be extended to Valdivia and Puerto Corral on the Pacific.

Supplementary Notes on the Pampas.

We have thus completed a descriptive traverse of the continent from the Atlantic to the Andes, essentially along the parallel of 41° south. This traverse corresponds with the zone of accurate topographic surveys and the regions of which we have definite knowledge. Our reconnaissance extended north to the Rio Negro and south into the territory of Chubut. In ord to complete the description we may give an account of the adjacent area both north and south.

The district of the interior basins is characteristically developed nort of our surveys in what is known as the Bajo del Gualicho or Devil's Deep a depression of great length, which is probably to be divided into severa distinct basins whenever it shall be topographically surveyed, but whicl appears as a low area trending northwest and southeast from near the Ric Negro in latitude 67° to a point north of San Antonio. The deepest point is near the eastern end and it is estimated, by aneroid barometer observations compared with the railroad at Valcheta, to be 30 metres below sea-level. On old maps the depression is described as an ancient course of the Rio Limay, but it is not an erosion channel and has never been occupied by the Limay or the Rio Negro.

The slopes of this bajo descend from high plains covered with Tertiary gravels and are more or less strongly eroded by intermittent streams, which run only after heavy rainfall. As a rule the surface is covered by wind-blown material, or by the alluvial deposits in the flat playas that occur along the bottom of the hollow. There are salt plains, gravelly stretches where the wind has blown away the finer soil, and sand dunes. Much of the region has a distinctly desert aspect. Surface water is scarce and that in wells is commonly salt, although, occasionally, fresh water is found. One well which was sunk 105 metres near the deepest part of the Bajo del Gualicho is said to have yielded an artesian flow of hot water. Here and there, where the strata of the surrounding plateaus are exposed, we find the marine Rocanean or Patagonian, or fresh-water beds which are assigned to the same general geologic epoch. Volcanic eruptions appear to be wanting and lava fields have not been described from the region east of the Huincul-Mapu, which ends about longitude 68°, latitude 40°.

The high plateau of the Huincul-Mapu, which occupies the region between our surveys and the Rio Limay, has already been described as a broad plain about 1,000 metres in elevation and surmounted by remnants of marine strata capped by lava flows which constitute more or less isolated or connected buttes.

South of the traverse of our survey a zone of lava plateaus extends from about longitude 66° westward to the Anecon Grande group of volcanic peaks. The character of this plateau and of the prominent volcano, Sumcura, lying south of Valcheta, has been described, as also the manner in which the plateau feeds the streams that flow northeastward into the Bajo del Valcheta. From north to south the lavas occupy most of the area between latitudes 41° and 42°, and probably extend southward beyond 42° between longitudes 67° and 68°.

Referring now to Maquinchao (about longitude 68° 30′, latitude 41° 15′) and Fofocahuel (longitude 71° 20′, latitude 42° 30′), we note on the road connecting the two, a break in the volcanic plateau and a region of somewhat different structure. The oldest rocks, comprising granites and other elements of the basement complex, together with Cretaceous sandstones and Patagonian sediments, were there eroded into valleys of considerable depth before there occurred certain eruptions of tuffs, which extensively filled the valleys and which we attribute to the later Miocene. The result was that in excavating new valleys, drainage lines have in some cases redeveloped the old valleys or cut canyons across earlier divides. One may observe the heads of the ancient and modern streams coinciding upon the higher slopes of the volcanic centres such as Anecon Grande, and then trace the old valleys between ranges of half buried hills of granite or other old rocks margined by terraces of the tuff deposits. The streams often leave the valleys which their predecessors followed and, crossing a col, pass through a canyon into another drainage basin. These crosscuts had already been observed north of Anecon Grande when the opportunity occurred to make a reconnaissance of the southern region in which they are much more extensively and characteristically developed. The streams that flow from the southern side of the lava plateau, or from the region of resurrected hills, either die in the plateaus on the slope toward the Chubut or, reaching that river, become tributary to it.

Geologic structure of the Pampas.

The references which have been made to geologic formations in the preceding pages will have prepared the reader for the recognition of various formations whose time range is from pre-Cretaceous, probably Paleozoic, to Recent; but this long period of time is but very meagerly represented by deposits. During the greater part of the history which we can trace, northern Patagonia has been, as it is now, a continental area. The submergences to which it has been subjected have been occasional, and possibly never at any one time complete. We recognize certain formations or groups of formations, and assign them provisionally to the geolgogic epochs indicated in what follows, but it must be understood that even where we have fossils, the collections have not yet been studied and their correlation remains as yet indeterminate.

The oldest rocks of this region are metamorphosed schists of sedimentary origin in which a small quantity of carbonaceous matter has been recognized. They are intruded by granites, and the granites were associated with or followed by great outflows of rhyolite. The relations of the granites and rhyolites constitute a petrographic problem of great interest and one upon which the detailed study of the region will eventually throw important light, as the exposures are numerous and the two varieties of eruptive are found in close proximity to each other. Messrs. WASHBURNE and PEMBERTON have given some attention to the relations, but their field observations do not suffice to determine whether there are gradations from the granite into the rhyolite or whether we should consider the masses as distinct. The volume of rhyolite is very large, as is also that of the granites, and it is obvious that the region was, in the earliest geologic epoch of which we have any information, one of intense and prolonged eruptive activity. This character it has maintained even down to the present.

During an epoch corresponding probably with the later part of t Cretaceous period an extensive series of red sandstones were laid down. Th have been described by SANTIAGO ROTH and others who have written on t geology of the valley of the Rio Negro. They are but sparsely represente in the region of our survey and apparently do not extend east of Maquinchao If they were formerly deposited over the section to the eastward they hav been eroded. The Cretaceous strata are generally somewhat disturbe but do not exhibit distinctly folded structures. The late Cretaceous or earl Eocene is represented by the Rocanian formation originally described b ROTH from the type locality of Roca on the Rio Negro. WASHBURNE ha found remnants of it with the characteristic fossils at various isolated localitie throughout northern Rio Negro and as far south as Maquinchao, and ha determined some new stratigraphic relations in which it occurs. The Rocanian has not been found in contact with the Patagonian, which is supposed to succeed it and it is possible that the two will be indentified as belonging to the same stratigraphic horizon, in which case the Rocanian should probably be referred to the early Tertiary rather than to the late Cretaceous.

The Patagonian formation, or strata which, from the field identification of the fossils, we consider probably to be representative of it, occurs extensively over the Pampa region from the Atlantic to the Cordillera de los Andes and in that mountain zone itself. It is thus a very widespread, but rather thin formation, composed in part of marine beds, and in part of fresh-water deposits which are stratigraphically continuous with the marine strata and undoubtedly belong to the same epoch. The thickness of the Patagonian strata rarely exceeds 100 metres. They were deposited upon the very uneven surface of the old basement complex, and it is probable that the fresh-water deposits represent estuaries. Fossil trees of large size, up to three feet in diameter, are locally abundant, and are known in various districts in which the formation occurs, from Valcheta to and in the Andes. To the east we have not recognized volcanic deposits as a part of the Patagonian formation, but from the region of Anecon Grande westward andesites, dacites, and tuffs constitute a large part of the body of the formation, and including them its thickness swells to 1,000 metres or more. The Patagonian beds east of the Cordillera are generally undisturbed except where local volcanic activity has tilted them, but in the foothills of the Andes, especially in the vicinity of Lago Nahuel Huapi, the strata are strongly folded and even overthrust locally.

There is a zone of the Patagonian extending southeastward from the basin of Lago Nahuel Huapi, in which these effects of disturbance are strongly marked, the synclines being so folded that the western limb is vertical or overturned. The belt is, however, not more than 10 kilometres in width, and the phenomena is a local rather than a general one. Its northern limit is south of latitude 41°, and it probably does not extend southward beyond latitude 41° 40′. The structure of the Andes as a whole is one of regional elevation accompanied by faulting and not one of folding.

The several formations which we have thus briefly described were somewhat elevated and deeply eroded during an interval following the deposition of the early Tertiary (Patagonian) sediments. In the valleys which were thus developed, deposits of volcanic ash, mud flows and gravels were laid down, and part of these may be taken to represent a middle or late Tertiary epoch of eruptive activity. They are widespread throughout the region west of Maquinchao; they are found in all the valleys which radiate from Anecon Grande, and upon the eastern flanks of the Andes they filled the old valleys to a depth of from 100 to 200 metres and produced extensive bordering plateaus or valley floors upon which a gravel formation was widely spread. Inasmuch as the soft tuffs were not materially, if at all, eroded before the gravels were laid down upon them, we infer that the gravels followed immediately upon the close of the tuff eruptions. With them the history of Tertiary deposition appears to have come to a close and that of erosion, which has continued down to the present time, to have begun.

As the next deposits which were laid down were those of a Glacial epoch of high antiquity, we would infer that the latest tuffs and gravels are probably of Pliocene age, and that the Tertiary closed with the elevation of the Andes, which resulted in the development of the canyons that the earliest Pleistocene glaciers occupied and deepened.

THE CORDILLERA OF THE ANDES.

Description.

The great mountain chain of the Andes, stretching along the entire Pacific coast of the continent and attaining altitudes of more than 7,000 metres in its highest peaks, has strongly impressed upon the minds of explorers and students the idea of an enormous mountain barrier, distinctly separating the lowlands of the Pacific coast from the vast, low plains of eastern South America. So fixed is this conception that it has affected the deliberations of statesmen and the relations of nations. The conception of a dividing wall, nowhere easy of passage and in many places impassable, was the fundamental idea according to which the boundary between Argentina and Chile was to have been traced, when, in 1881, the two nations agreed upon a treaty defining that line. Throughout the greater part of its extent the conception held true, and the engineers traced a well-defined crest which, following the high summits of the Andes, coincided with the divide of the waters between the Pacific and the Atlantic. But from latitude 38° southward a different geographic condition was found to exist. The Cordillera spreads out and divides into parallel mountain ranges. The higher crest sometimes lies in the western range, sometimes in the eastern. Rivers rising in the extreme west of the mountain belt flow to the Atlantic, whereas others east even of the eastern Cordillera, in the Pampas themselves, flow westward across the entire zone of the Andes to the Pacific. Here was confusion for the treaty-makers. A mountain wall had become a labyrinth of heights and valleys pierced in many places by rivers which wound in zigzag courses, now toward one ocean, now toward another, and a boundary as fixed by a line along the highest crest of the Cordillera was found to diverg widely from a boundary traced on the continental divide between the At lantic and the Pacific. Fortunately for both Argentina and Chile, th treaty-makers had with great wisdom provided that any dispute should b settled by arbitration, and eventually, after twenty years of discussion, th arbitrator, King EDWARD of England, in 1902 determined a compromise boundary line between that on the highest crest and that on the divide of the waters.

The line thus determined by arbitration is the western boundary of the region studied by the Comisión de Estudios Hidrológicos, from latitude 39° 40′ to 43° 40′. The area covered by the studies is 31,000 square kilometres. It includes in latitude 40° the disputed basin of Lago Lacar, which Chile claimed because the waters flowed to the Pacific, but which was given to Argentina because it is bounded on the west by the great Ipela range, which in this region is unquestionably the main chain of the Cordillera. It includes also a more extended district south of latitude 41°, where a central valley lies longitudinally between the western and eastern ranges, which are equally high. Here are the lakes of Gutierrez and Guillelmo, the rich valley of El Bolson, and the headwaters of the great river Ftalenfu, with the valley of the 16 de Octubre, all of which were claimed by Chile but in the division of contested territory were given by the arbitrator to Argentina. Between the disputed districts of Lago Lacar on the north and of the inter-Cordilleran valley on the south, there is the great transverse basin of Lago Nahuel Huapi, which stretches clear across the mountain zone and, heading in the western ranges, discharges by the Rio Negro into the Atlantic. Since the divide about the headwaters of this Atlantic watershed coincides with the crest of the Cordillera it fulfills the conditions of the treaty, and the territory which it enclosed was conceded without question to Argentina.

Enough has been said in the preceding paragraphs to show that the Andes of northern Patagonia do not constitute a simple mountain ridge. They are far more complex and, indeed, form a broad mountain zone from 60 to 100 kilometres in width, including many valleys and traversed by large rivers. A student looking at a plan of the river systems without indication of the mountains would never suspect how widely the greater heights are distributed. Should he infer that the serpentine line of the continental divide represented a continuous high ridge, he would be surprised to discover that in many places it descends into and crosses deep valleys. Should he ascend to the heights in hopes of discerning the great dominant mountain chain of the Andes, he may look off north, east, south and west over a bewildering multitude of summits which rise almost everywhere to an altitude even with his own. They are angular peaks surmounting a broad common base that is represented by high valleys and wide passes. Their common altitude is near 2,000 metres above sea. Few of them are less than 1,800 metres, and only rarely do individual summits exceed 2,300 metres. As we study the range we learn that the summits whose altitudes most closely approach uniformity are sculptured by erosion from the broad plateau-like mass of the older rocks of the Andes, whereas those isolated heights which here and there exceed 2,200 metres above sea are usually volcanic cones built up upon the plateau. The most renowned of these volcanoes is El Tronador (the Thunderer), 3,460 metres above the sea, which received its name from Friar MENENDEZ in 1791, when he described it as the mountain that is always thundering. At the foot of this great peak lies the most profound canyon and lake of the region, that of Nahuel Huapi.

Although this section of the Andes is, as described, a broad mountain zone of confused geographic features, it may be divided into two distinct regions, a northern and a southern, and the distinction may be expressed in the simple statement that in the northern district the valleys extend east and west across the mountain zone, whereas in the southern they range longitudinally from north to south within the Cordillera. The difference has its origin in the geologic conformation, in the structure of the zone. The northern section comprises the stretch of the Andes from latitude 38° to 41°, from Lago Alumine to Lago Nahuel Huapi. All of the streams within it rise in the Western Cordillera and flow eastward to join their waters in the Rio Colloncurá and the Limay, which flow in the depression that lies along the eastern base of the Andes; all of the streams except one. Lago Lacar, though once its valley belonged to this Atlantic family, has been taken away and now discharges its waters across the western range down the Pacific slope to the Chilean lakes.

In this northern section high transverse ridges extend eastward between the watersheds, and far from diminishing in height, in some cases attain greater elevations near their eastern extremities than in the western. They thus divide the section into individual basins and more or less effectively obstruct the passage from one to another within the wide belt of the Andean plateau. Where the valley floors vary from 600 to 800 metres in altitude above the sea, we must rise to passes that attain 1,000 to 1,200 metres in order to cross from one to the other. Each of the deep transverse valleys harbours a lake or a chain of lakes. Like the lakes of Switzerland and northern Italy, these are deep basins sculptured in the rock by the rock-laden ice of glaciers 1,000 metres or more in thickness, descending from the adjacent heights. Their shores are always picturesque and often precipitous. About their lower eastern ends are piled the glacial moraines of an ice period which is still represented in the little glaciers that linger about the high summits. As we descend the valleys of the streams we find in each case at a distance of several kilometres a much older glacial moraine which marks the outermost limit attained by the ice that filled these valleys during an earlier Glacial epoch.

Thus these valleys, descending from the Western Cordillera to the lowland that intervenes between the Andes and the high plateaus of the Pampas, range in character from deep gorges in the mountains to beautiful lake basins and wide stretches of gravel plains. Their waters flow in the direction of the western winds, in the direction in which the air currents become drier as they unload their moisture upon the mountains. Vegetation changes accordingly and the streams which gather from the deep forest shades of the mountain slopes and which linger in the cold rock-bound lakes, flow on in the broad sunlight of the treeless, grassy Pampas.

The section of the Cordillera south of Lago Nahuel Huapi differs from the northern in that a central valley traverses it from north to south, separating the high western and eastern ranges. From Lago Nahuel Huapi itself a deep pass, which is cut nearly to the level of the lakes, leads to Lago Gutierrez, whose waters still flow by that lake to the Atlantic. East of Gutierrez is La Sierra de La Ventana, and west of it El Catedral, both prominent summits among the Andean heights, yet between them one may pass from Lago Gutierrez to Lago Mascardi over a gravel plain which scarcely separates the two lakes, yet which divides the waters of the eastern and western oceans. Here the continental divide descends from El Catedral, passes across the plain between the two lakes, and descends again to the summit of the Sierra Ventana. A canoe launched on U-shaped Lago Mascardi would float from the upper right-hand arm to the bottom curve of the U, and might there pass westward down the outlet river, Rio Manso, to enter upon a winding course to Lago Hess and its tributary lakes and streams. Below Lago Hess it could not follow the river, which flows through a canyon and falls 220 metres to Lago Steffen. He who would go farther southward must retrace his steps to Lago Mascardi, and turning off from the bend of the U, pass by Lago Guillelmo across the gravel plains of the central valley beyond it, to the watersheds of the Villegas and Foyel, and from them follow the Arroyo de Los Repollos, to the Bolson. In so doing he crosses canyons and terraces, yet is continually shut in to right and left by the heights of the Eastern and Western Cordilleras. The Bolson and its neighbour, the Hoyo de Epuyen, are the deepest valleys in this section of the Andes, lying between 270 and 300 metres above sea, and 400 or more metres below Lago Mascardi. The temperature changes with the altitude. Frosts, which are common in the northern portion of the Central valley, are rare during the summer in El Bolson. It is a little paradise in the heart of the snowy mountains, ending in Lago Puelo, from which the Rio Puelo carries the waters to Chile. In the south rises the mountain group of Cerro Tres Picos and its attendant heights, which stretches clear across the mountain zone as a promontory of the Western Cordillera. On the east of El Bolson the continental divide, which follows southward along the summit of the Eastern Cordillera, sinks into the Pampas and, swinging eastward outside of the Andes, is marked by the ridge of a glacial moraine surrounding the basin of Cholila.

Southward from the heights of Tres Picos, a system of valleys tributary to the Rio Ftalenfu and by it to the Pacific, lies between the snowy Western Cordillera and the treeless heights of the Cordon de Leleque and the Cordon Esguel, which here represent the Eastern Cordillera. The valley zone between the ranges is wider than it is further north, the valleys themselves are in general broader, and the western chain is more dominant as compared with the eastern. Communication across it to Chile is more difficult and this circumstance no doubt influenced the arbitrator in tracing the boundary upon the western range and giving the valleys of Cholila, Lago Rivadavia, Lago Futalaufquen and 16 de Octubre to Argentina. These are rich, fertile and, due to the bracing mountain climate and pure swift-flowing streams, healthful. The Bolson, the Hoyo de Epuyen, Cholila, and 16 de Octubre, will support prosperous communities and play an important part in the future development of the Andes.

Geologic outlines.

Rock groups.—The rocks of that section of the Andes which lies between latitudes 39° and 44° are predominantly of igneous origin and comprise several types of granite, together with andesites, dacites and tuffs. With these are associated metamorphic schists and younger unmetamorphosed sediments, both marine and fresh-water.

There is but one group of these rocks to which we can definitely assign a geologic date. These are marine sediments containing a fauna which appears to belong to the Patagonian formation and is probably early Tertiary. All other rock groups and events of the history of the Cordillera must be described simply as having preceded or succeeded the deposition of those beds.

The pre-Patagonian rocks constitute a basal complex upon which the Patagonian was laid down. The oldest are quartzites and slates which may be of Paleozoic or Mesozoic age. They occur in isolated, discontinuous remnants on or in the eruptives which have disrupted them. Among the eruptives we recognize hornblende-granite, granodiorite, andesites and dacites, and it appears that there is a great variety of allied rocks. The granodiorite is younger than the hornblende-granite, in which it is intruded. The andesites and dacites are petrographically similar to the lavas of the Patagonian group, but are distinguished by more complex jointing, by absence of distinct bedding, and by their position below the Patagonian strata.

The Patagonian group consists of andesitic lavas, tuffs, sandstones, and conglomerates, shale-beds associated with lignitic coal, and marine deposits, which in some cases are fossiliferous sandstones and in others beds of heavy oyster shells. The strata represent the marine deposits laid down along the shores of volcanic islands or peninsulas during an epoch of pronounced vulcanism and erosion. The lavas and tuffs correspond with the flows and explosive eruptions.

In post-Patagonian time a strongly marked topographic relief was developed upon the older rocks and upon the Patagonian formations in consequence of an elevation which involved the folding of the sedimentary beds, and upon the eroded surface there was laid down an extensive group of white tuffs, composed almost exclusively of volcanic ash. Succeeding them in apparent conformability and continuity occur extensive gravel deposits, that have been traced from high mesas east of the Andes into that range, where they correspond to certain old valleys of the earliest phase of topographic sculpture that we can identify. As that phase is older than any

Glacial epoch it is assigned to the Pliocene, and the corresponding gravels also. The tuffs that underlie the gravels we shall refer to simply as late Tertiary. They may be not only Pliocene, but also in part Miocene. These latest deposits do not share the folding or disturbance of the older rocks except that they have been uplifted with the entire mass of the region.

Structure.— The structure of the basement complex is an intricate one, involving schistosity and the relations of various intrusive masses. Our survey does not suffice to distinguish these ancient structures.

The Patagonian formations have an original bedded structure which is common to the lava flows as well as to the tuffs and sediments, but the thick, rigid lavas share only in a minor degree the folded structure, which is well developed in the sedimentary beds in certain localities. An area of sandstones and conglomerates, which are partly marine and partly fresh-water deposits, occurs southeast of Nahuel Huapi, on the eastern flank of the Andes. The strata have been sharply folded. The type of structure is one involving anticlines and synclines with a certain amount of incidental overthrusting from the west. This structure is limited to the area of sediments and can not be considered as characteristic of the Andean Cordillera as a whole. It is a local and not a general phenomenon. The massive and intricate structure of the basement complex is such as to prevent the folding of the range in general.

Normal faults are well developed. They extend longitudinally along the central portion of the range, sometimes singly, sometimes in pairs, and vary in throw from nothing to 4,000 feet or more. At their extremities they pass into monoclinal flexures. Their existence is demonstrated stratigraphically by the juxtaposition of Patagonian sediments and rocks of the basement complex, the sediments lying in deep valleys at the foot of lofty precipices of the older rocks. In certain areas the physiographic character of the valley and the mountain surfaces is sufficient to indicate faulting or flexure in a manner which would suffice to demonstrate the fact, even if the stratigraphic evidence were lacking. It is also evident that the precipitous faces of some of the high ranges are fault-scarps.

Orogenic history.— The earlier history of the Andes as a mountain range is to be traced in the character and relations of the pre-Tertiary and Tertiary rock groups. It is evident that intrusions of granite occurred during the Mesozoic, or earlier. The variety of granites and the intrusive relations of one into another indicate the probability of different epochs of intrusion. The extent to which the granites had been uncovered by erosion when the early Tertiary formations were laid down proves that the region had been elevated during the process of intrusion, or afterwards. Probably there had been several elevations of the Andes before the Tertiary. The fact that Jurassic slates of the southern Andes are metamorphosed and intruded by granites suggests activity in this South American region contemporaneously with that which affected the Jurassic of California, Alaska and China.

The petrographic studies of our collections may throw light on these questions, but will probably not change the conclusion that the zone of the Andes had been repeatedly intruded and uplifted before the Tertiary.

We recognize somewhat more clearly the conditions and character of early and later Tertiary volcanic activity. By the study of the rock groups we trace the history down to the Pliocene or possibly early Pleistocene. There the sequence of pre-Glacial formations ends and the further evidence is expressed in features of stream and glacial erosion and aggradation. They demonstrate that, after a period of deep erosion, the Andes of this region were again uplifted in late Tertiary and early Pleistocene.

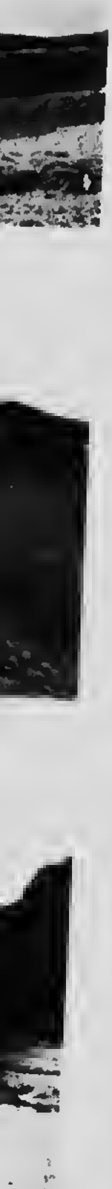
A discussion of the physiographic history of the range, covering this latest uplift and the phenomena of erosion resulting from it is given in the accompanying article on the Physiography of the Andes.

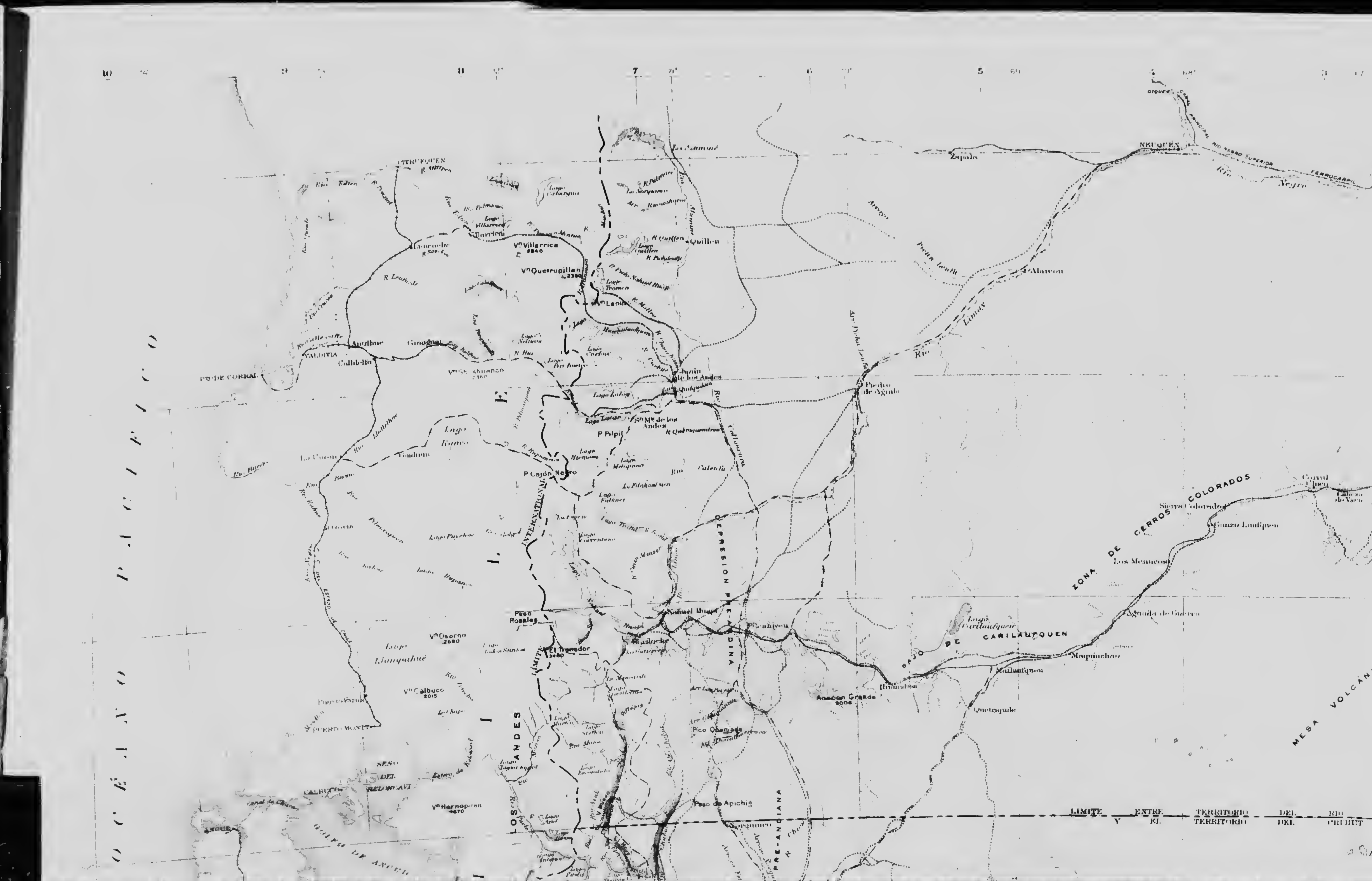
FIG. 1.

FIG. 2.

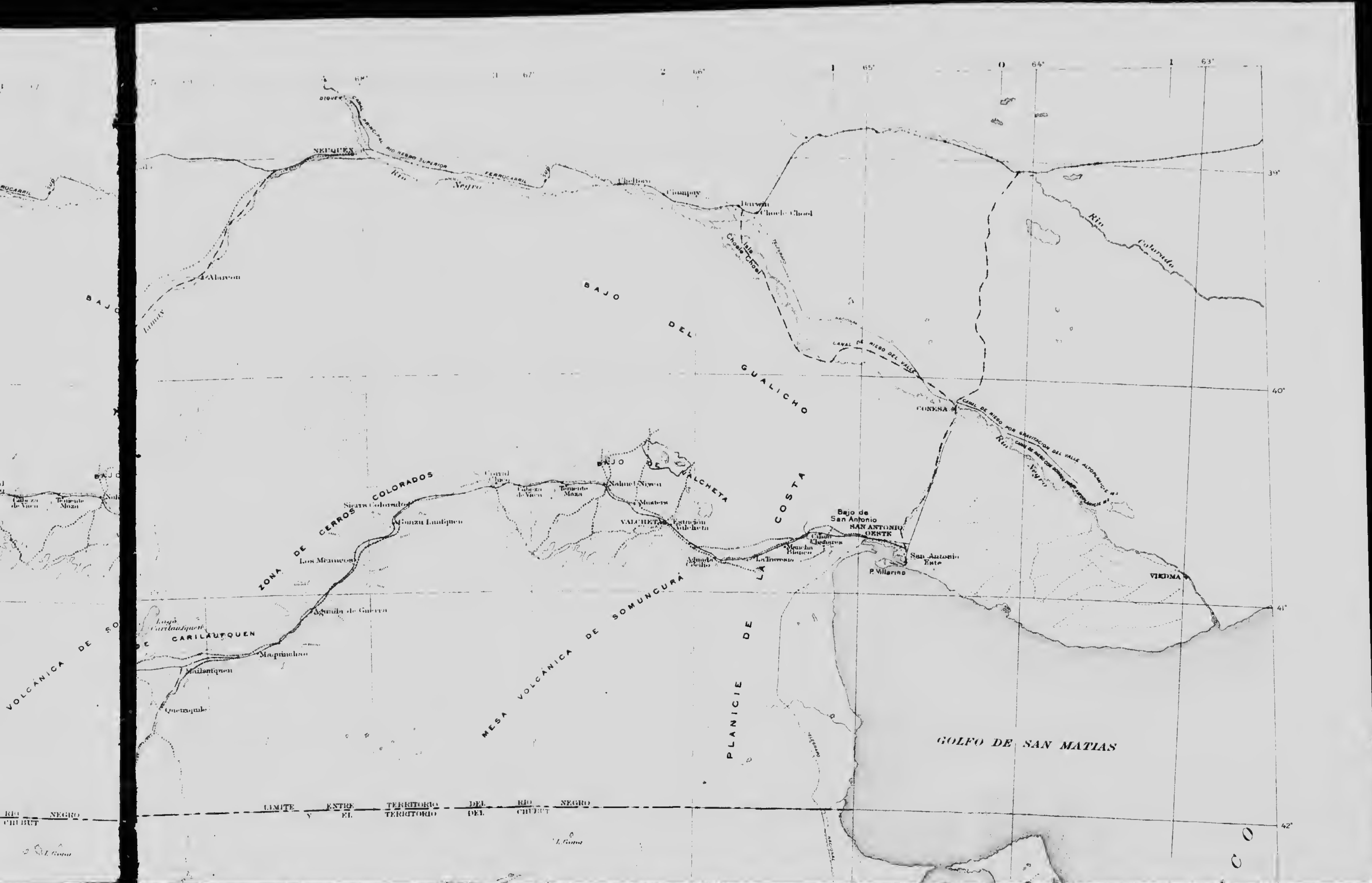
FIG. 3.

Plate I.





OCÉANO PACIFICO
NEUQUEN
Zapala
Rio Negro
FERROCARRIL
Alarcon
Rio Limay
Piedra del Aguila
ZONA DE CERROS COLORADOS
Sierra Colorada
Los Menucos
BAJO DE CARILAUFQUEN
Lago Carilaufquen
Maquinchao
MESA VOLCÁNICA
DEPRESION PRE-ANDINA
LIMITE INTERNACIONAL
LOS ANDES
Vn Villarrica 2840
Vn Quetrupillan 2360
Vn Lanin
Quillen
Junin de los Andes
Sn Mn de los Andes
Lago Lacar
P Pilpil
P Cajon Negro
Nahuel Huapi
Paso Rosales
Vn Osorno 2660
El Tronador 3460
Vn Calbuco 2015
Lago Llanquihue
Lago Ranco
PUERTO MONTT
Puerto Varas
VALDIVIA
Pto DE CORRAL
PITRUFQUEN
Anecon Grande 2008
Pico Quemado
Paso de Apichig
Vn Hornopiren 1670
SENO DEL RELONCAVI
CALBUCO
ANCUD
Canal de Chacao
GOLFO DE ANCUD
LIMITE ENTRE TERRITORIO DEL RIO
Y EL TERRITORIO DEL CHUBUT



68°
67°
66°
65°
64°
63°
39°
40°
41°
42°
NEUQUÉN
Canal Principal Río Negro Superior
Ferrocarril
Río Negro
Chelforo
Chimpay
Darwin
Choele Choel
Isla Choele Choel
Alarcón
BAJO DEL GUALICHO
Canal de riego del valle
CONESA
Canal de riego por gravitación del valle
Río Colorado
Río Negro
BAJO DE VALCHETA
Nahuel Niyeo
VALCHETA
Estación Valcheta
Teniente Maza
Cabeza de Vaca
ZONA DE CERROS COLORADOS
Sierra Colorada
Los Menucos
Aguada de Guerra
Laguna Carilauquen
DE CARILAUQUEN
Maquinchao
Aguada Cecilio
Bajo de San Antonio
SAN ANTONIO OESTE
San Antonio Este
P. Villarino
VIEDMA
PLANICIE DE LA COSTA
MESA VOLCÁNICA DE SOMUNCURÁ
VOLCÁNICA DE SO
GOLFO DE SAN MATIAS
LIMITE ENTRE TERRITORIO DEL RIO NEGRO
Y EL TERRITORIO DEL CHUBUT

GENERAL MAP OF NORTHERN PATAGONIA

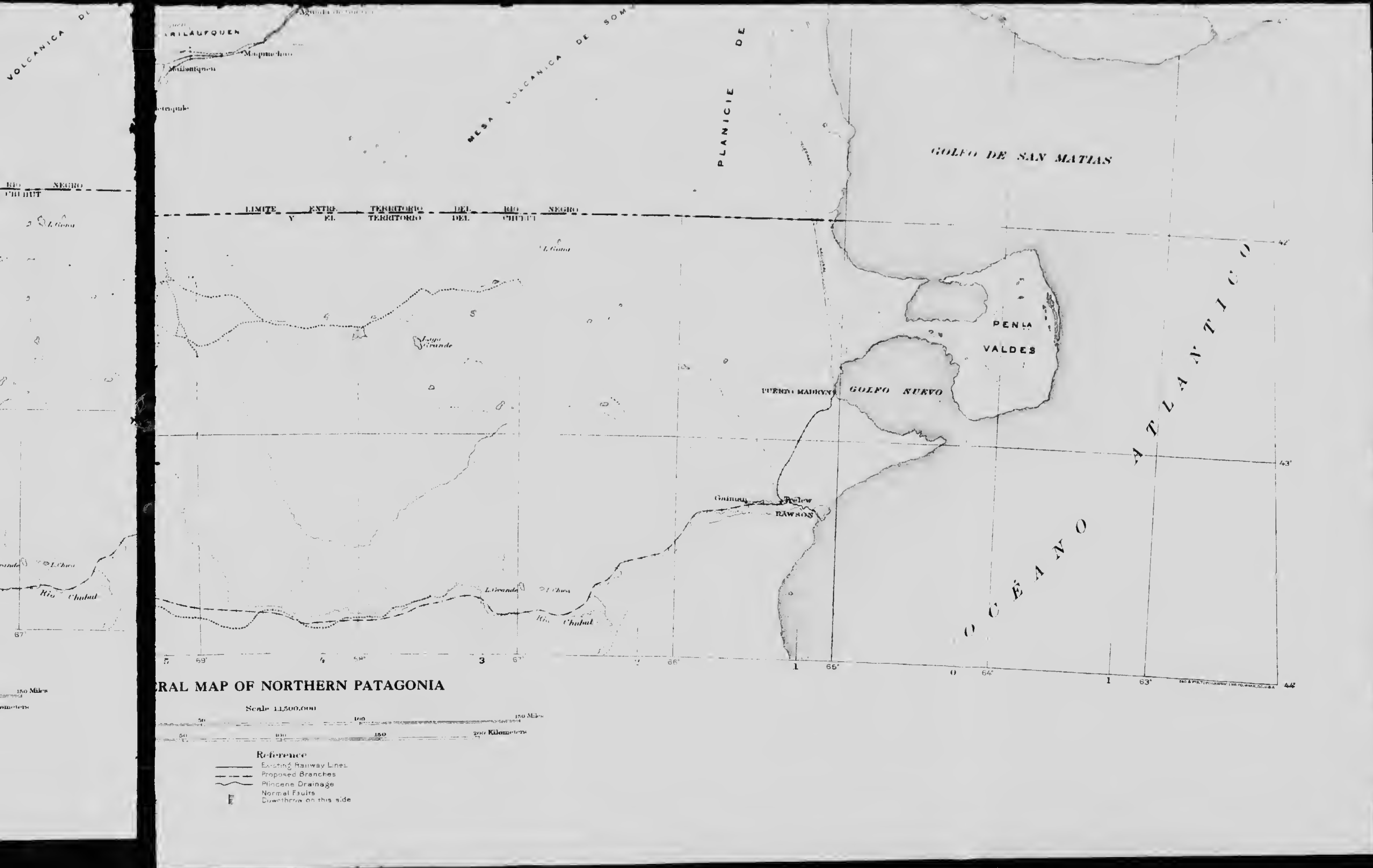
Scale 1:1,500,000

0 — 50 — 100 — 150 Miles

0 — 50 — 100 — 150 — 200 Kilometers

Reference

- Existing Railway Lines
- Proposed Branches
- Pliocene Drainage
- Normal Faults Downthrow on this side


GOLFO DE SAN MATIAS
MESA VOLCANICA DE SOM
PLANICIE DE
Maquinchao
LIMITE ENTRE TERRITORIO DEL RIO NEGRO
Y EL TERRITORIO DEL CHUBUT
PEN LA VALDES
GOLFO NUEVO
PUERTO MADRYN
Gaiman
Trelew
RAWSON
OCÉANO ATLANTICO
Lago Grande
L. Grande
L. Chica
Rio Chubut
RAL MAP OF NORTHERN PATAGONIA
Scale 1:1,500,000
150 Miles
200 Kilometers
Reference
Existing Railway Lines
Proposed Branches
Pliocene Drainage
Normal Faults
Downthrow on this side

PHYSIOGRAPHY OF THE CORDILLERA DE LOS ANDES BETWEEN LATITUDES 39° AND 44° SOUTH.

BY

BAILEY WILLIS,

United States Geological Survey, Washington, D.C.

With a map

INTRODUCTION.

The region which is to be described in the following article is that part of the Cordillera de los Andes which lies between latitudes 39° 40' and 43° 40'. It therefore comprises a section 450 kilometres (280 miles) in length, which falls in the zone of temperate and humid climate, between Argentina and Chile. The greater part of the mountain region is Argentine, as the boundary with Chile follows the western crest of the broad Cordillera.

The geography of this mountain region was first made known in any degree of detail through the labours of Dr. FRANCISCO P. MORENO and his colleagues, whose surveys were made on behalf of their country, Argentina, in the boundary dispute with Chile, which began in 1881 and continued until it was settled by the arbitration of King EDWARD in 1902.

Extensive surveys were carried on by both governments in order to procure [illegible]ence which should be produced before the Arbitration Commission, and [illegible] a result, especially of the work of Dr. MORENO, the Andean region from latitude 39° to latitude 52° has been more carefully mapped than any other large area of either Argentina or Chile. We know that it is not a mountain ridge, but a broad mountain zone. We know that the summits within the zone rise in general to a common, nearly uniform altitude above the sea. It has been determined that seven large rivers rising east of the mountain zone flow through it to the Pacific, in deep and tortuous channels. Furthermore, it is a region of numerous lakes, many of them of notable size and characterized by the features of rock basins which have been deepened by glaciation. Recent studies have shown that there were at least two distinct periods of glaciation, which were separated by a long inter-Glacial period. We have learned also that normal faults traverse the range longitudinally and are the cause of certain longitudinal valleys, which lie between the Eastern and Western Cordilleras. There is no evidence of transverse faults crossing the range.

We thus approach the detailed study of this mountain zone with quite a different concept from that of the treaty makers of 1881. We shall recognize many distinct mountain groups, which yet seem related as elements of a broad uplifted zone. We shall have to distinguish effects of faulting, of erosion by streams, of retrogressive erosion and stream capture, and of erosion and damming by glaciers, in tracing out the development of the intricate river systems which occupy the Andean valleys and canyons.

A brief description of the rock groups and structure observed by geologists of the Comisión de Estudios Hidrológicos has been given in *The Forty-first Parallel Survey*. The following pages present the views of the writer on the physiographic history of the Andes.

PHYSIOGRAPHIC EPOCHS.

A careful analysis of the topographic features of the Andes has led to the recognition of the following physiographic epochs: (1) epoch of mature erosion and low relief expressed in the highest summits and valleys; (2) epoch of elevation and deep canyon-cutting; (3) epoch of early glaciation; (4) inter-Glacial epoch; (5) epoch of latest glaciation; (6) post-Glacial or present epoch.

The earliest of these epochs of erosion corresponds with the gravels, already referred to as probably Pliocene. We may then arrange the successive epochs as follows:

Stages.	*Characteristic.*	*Period.*
(n + 1).	Mature topography.	Pliocene or earlier.
(n + 2).	Elevation and faulting. Canyon development. Stream capture.	Pliocene or later.
(n + 3).	Earlier glaciation.	Pleistocene.
(n + 4).	Inter-Glacial.	
(n + 5).	Later glaciation.	
(n + 6).	Post-Glacial.	

It appears from the study of the relations which the present topographic features bear to one another that the river courses have been greatly changed since the (n + 1) epoch and the continental divide has been shifted by the diversion of the headwaters of certain Atlantic tributaries to competing Pacific streams. The Quilquihue waters, the Rio Chubut, and the Rio Tecka are the streams which have lost their original heads in the area under consideration. It will be shown that these diversions were due to the normal process of retrogressive stream erosion under conditions which gave to the Pacific stream in any individual case the advantage of steeper fall and shorter course to base-level as compared with the situation of the Atlantic tributary. The captures were accomplished during the (n + 2) epoch, when the elevation, normal faulting of the mountain mass, and consequent acceleration or retardation of the rivers caused shifting of divides and gains or losses of watersheds. The changes therefore occurred before the Glacial period and are not attributable to glaciation.

The conclusion of the preceding paragraph that the divides were shifted by stream capture before the earliest Glacial epoch of the Andes applies particularly to the diversion of Atlantic tributaries to canyons which traverse the Western Cordillera, and replaces the explanations hitherto given that attribute those canyons to faulting or to glacial erosion. Faulting is discarded except in so far as it is recognized as a longitudinal structure, not as a transverse one, on the range. Its effect was to retard, not to accelerate the rivers which crossed the faults. Glacial erosion could not have opened the canyons across the Western Cordillera, since the conditions of a high head of ice and confinement in a narrow gorge, which are essential to erosion by a glacier, could not exist on a dividing ridge. The elimination of faulting and glacial erosion as causes of the transverse canyons in the Western Cordillera is a negative which agrees with the positive evidence of retrogressive erosion in establishing the latter as the real cause.

Notwithstanding the conclusion that glaciation did not occasion the transfer of Atlantic tributaries through the Western Cordillera to the Pacific, it is recognized that glaciers did interfere with the river courses in the Cordillera and in some instances established the continental divide on glacial moraines east of the Eastern Cordillera. They transferred certain drainage areas from the Atlantic watershed to the rivers of the Central Cordilleran valley and thus to rivers that had previously been diverted to the Pacific. These glacial diversions are due to damming, to the formation of lakes, and to the cutting of canyons by new lake outlets. The evidences are clear and unmistakable, and having been observed by various explorers, have led to the conclusion that the entire diversion in any one case was due to one and the same cause, glaciation. A more careful analysis distinguishes the earlier effects of retrogressive erosion from the later interferences by glacial damming and shows that the processes which have transferred the continental divide to the eastern side of the Cordilleran plateau, or to the Pampas still east of it, were the normal processes of retrogressive erosion and glacial obstruction; the earlier and greater work of stream capture was accomplished before the later and minor effects of glaciation were added to them.

Since writing the above I have received the excellent article by QUENSEL[1] in which he states his observations on the glaciation of the southern Andes. His observations in the south and mine farther north lead us to agreement on the following essential points:

(1) The present continental divide, where it now lies east of the Cordillera, commonly follows morainic ridges, which were built across wide pre-Glacial valleys by ice tongues protruding eastward from the mountains. Canyons corresponding to the head-waters of these valleys were profoundly deepened and sculptured by the ice descending into them from the Andean

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[1] *On the Influence of the Ice Age on the Continental Watershed of Patagonia;* Bull. Geol. Institute of Upsala, Vol. IX.

heights. On the retreat of the ice the basins enclosed by the moraines across the valleys were filled with lakes, which found low outlets to the west.

(2) The Cordillera was traversed by low passes (valleys of erosion) in pre-Glacial time, and these had a marked influence in determining the courses of the rivers that flowed from the glacial lakes to the Pacific.

Mr. QUENSEL is inclined to lay more stress on the deepening of the passes in the Western Cordillera than I would where they cross divides, as the conditions for glacial erosion were not favourable at those passes where I have seen them, whereas the relations of the streams are those which should result from capture by retrogressive erosion. This fact QUENSEL does not appear to have recognized. I quote the following passages from his interesting paper:

"FORMATION OF SUB-ANDINE LAKES."

"Before proceeding farther south, I will here briefly dwell on the formation of the depressions of the typical sub-andine lakes, as found in Lagos Buenos Aires, San Martin and Argentino. In the first place, an interesting fact is the near correspondence in height between the largest lakes: Lago Argentino 200 m., Viedma 250 m., San Martin 200 m., Pueyrredon 199 m., and Buenos Aires 217 m. I have several times already emphasized that the eastern parts of those lakes seem to be a direct continuation of the transversal valleys. Imagining the glacial deposits, which head these valleys, removed, the level of the lake would be greatly reduced and the valley would stretch farther westward. It is therefore necessary, when seeking to explain the formation of these lakes, to keep this in mind, as far as their eastern part is concerned. On the other hand the western fiords of the lakes with their perpendicular shores present an aspect so totally different as to claim another explanation. They have every resemblance to the Alpine lakes of other mountain landscapes and without doubt ice has played a principal part in moulding their present form. Descending the steep mountain sides, the glaciers reach their maximum of erosive power. But farther eastward the glacier, which had once filled the whole depression, has not had the same power to erode, the fall there being insignificant, if any, and in this case the ice would spread out more as in a piedmont-glacier. Of course a series of soundings in these lakes would be most interesting and doubtless gives a definite answer as to the mode of formation of these depressions. There is, however, every reason to suppose that the deeper part of the lakes is to the west, the whole topography of the country indicating this to be the case, especially by analogy with the very similar inlets farther south, where the depths are known. I will return to this question later on after having dealt with the general formation of the southern inlets. In trying to solve the formation of the sub-andine lakes, it is therefore necessary not simply to classify them, as Ameghino and Hatcher do, as tectonic depressions, but assume that in their eastern parts they represent the continuation of the erosion valleys of the Pampas, whereas their western parts have without doubt to a great extent been moulded by glacial erosion. In pre-glacial time the watershed would then have lain along the eastern slopes of the Cordillera."

"As to the trans-andine passes, there can be no doubt that they are old pre-glacial depressions, and that therefore in pre-glacial time low passes have existed at intervals, transversing the whole Cordillera. Glacial erosion may have done much to deepen them, whereas, from reasons already mentioned, post-glacial erosion can not have played any significant part."

"In continuing south of Lago Argentino several breaks through the Cordillera are again met with, but differing from the trans-andine valleys I have described by being submarine, that is to say, consisting of narrow fiords or channels transversing the Cordillera range, and at its eastern side widening out to considerable inlets. The analogies with the trans-andine valleys and the sub-andine lakes are, however, so numerous and so remarkable, that it seems as if on the whole their existence were caused by the same geological powers, the only difference being that the land to the south lies essentially lower, the valleys therefore being represented by fiords, the lakes by inlets of the ocean."

"CONCLUDING REMARKS."

"I will now in a few sentences try to combine the principal conclusions which may be drawn relating to the post-glacial evolution of the districts dealt with."

"Firstly, the ice-divide during the ice age has in general followed the central Cordillera range, whereas the watershed of the present day, often consisting of glacial deposits, is principally situated considerably to the east of the mountains indicating the limits of *the latest Cordilleran glaciation.* The transverse valleys of the Pampas and the eastern parts of most of the sub-andine lakes, which orographically belong together, are nearly separated by glacial deposits. They are to be considered as valleys of erosion of pre-glacial age, probably formed as the land rose after the last mighty Pliocene transgression."

"Until toward the end of the ice age the trans-andine valleys must have been filled with ice, barring any outlet in that direction. The drainage of the eastern Cordillera must at that period have followed the pre-glacial Pampean valleys to the Atlantic. High morainal ridges and quantities of glacial detritus have been deposited in the upper parts of the valleys by the receding ice, in many cases barring the rivers and thus forming extensive ice-dammed lakes. Through the very inconsiderable fall of the transversal valleys, the rivers have had but a small erosive power, and have therefore not been able to cut through the extensive glacial deposits and drain off the lakes, which, hollowed out by powerful glacial erosion, without doubt contain depths far below the level of the ocean. The passage of these former outlets through the morainal landscape is in most cases recognizable. As the last ice in the trans-andine gorges disappears, a lower pass has thus been opened in this direction, the whole drainage system has suddenly been reversed, and the level of the lakes more or less lowered; in some cases it is possible, that the pass to the west has been low enough to completely drain off the former ice-dammed lake."

"In pre-glacial time low passes of erosion must have existed in many places in the Cordillera. Through the accumulation of ice in these depressions, the passes may have been essentially lowered by glacial erosion, mighty streams of ice from the central parts of the mountains following these depressions both east and west. The western parts of the sub-andine lakes in every way resemble the fiords of mountain regions, which once have been the seat of glaciation and have doubtless to a great extent been formed by glacial erosion. A very marked tendency which many of the fiords of the sub-andine lakes have of stretching in a north-south direction is in all probability due to tectonic depressions or faults caused by the forming of the Cordillera range, to which they are parallel."

MATURE TOPOGRAPHY, (n + 1) STAGE, PRE-PLEISTOCENE.

In ascending from the rivers or lakes of the southern Andes one encounters a change of slope and passes from the steep canyon side into a gentler valley or onto a mountain spur at an elevation which varies from 1200 to 1600 metres above sea. Standing at this level, the observer recognizes two distinct topographic phases. The one below him is that of the immature canyons. The one above him is that of the mature valleys and divides of the region above the canyons. The latter is the older and is first to be described.

The characteristics of the mature topography of the upper zone are broad valleys, sharp ridges, acute peaks and sometimes fairly extensive plateaus. The last, as we shall see, are not typical and are probably structural rather than erosional features.

The broad valleys lie between mountain spurs, and take their rise in the higher peaks. They are in all respects characteristic valleys of erosion. In the (n + 1) stage they had reached a period of development in which the autogenous streams had attacked the entire surface so that their headwaters met on the sharp divides; and further, the valley slopes were sufficiently reduced so that residual deposits accumulated upon them. Remnants of these residual accumulations still remain on the eastern mountains, although in general they have been replaced by glacial deposits of various kinds, which gathered on the same gentle slopes. Thus in the character of the divides and the conditions of the valleys, the topography of the high zone is typically mature.

No older phase of topographic development is now recognizable in the southern Andes, although there undoubtedly was an earlier history of the range as a mountainous region, for the Miocene and Eocene eruptions must have been accompanied by the development of marked relief. Indeed, in certain localities an eroded surface may be seen beneath the Miocene tuffs. Some corresponding features of the Miocene topography may remain in the plateaus of Patagonia, east of the Andes. But in the Andes themselves it is doubtful if any topographic feature can be assigned to so remote a date as the Miocene. Since, however, the mature topography of the Andean plateau antedated by a considerable period the earliest glaciation of which we have records in the Andes, we may plausibly assign it to the Pliocene. It is a surface characterized by a relief amounting to 500 metres between hilltops and nearby valleys, and therefore represents a low mountain range; it is not a plain, nor any approach to a plain. The uniformity of summit altitudes does not demonstrate an earlier peneplanation, in the writer's present opinion, as he has repeatedly observed such uniformity in cases where other evidences of planation, such as flat summits covered with residual soil, were wanting. Since peneplanation is a process requiring prolonged steadiness of the surface in relation to base-level and the geologic evidence clearly shows that this Andean region has been one of frequent, if not constant, volcanic activity throughout the Tertiary, the proof of peneplanation should be very definite to be conclusive. The approximate accordance of acute summit levels is not adequate proof, since that approximation may be reached in progress toward peneplanation in that stage of advanced maturity which the summit peaks and ancient valleys of the Andean plateau present. The writer therefore regards maturity as the stage represented, and does not think that the Andean range in this region was reduced to a peneplain.

Referring to this mature stage of topography according to its probable geologic date, we may say that the Pliocene topography is widely recognizable through the southern Andes. It is plainly to be seen in all the broader mountain masses. See, for example, the photographs contained in the Argentine Evidence before the Arbitration Commission of 1902. We may give descriptions of some characteristic occurrences of the Pliocene stage of mature development.

About latitude 40° 20′ and longitude 71°, the Rio Calenfu issues from the Cordillera and flows eastward between gravel mesas to join the Collon-curá. In the Cordillera the Calenfu flows in a deep canyon with rocky walls, which are precipitous or very steep; its elevation is about 800 metres, and the walls of the canyon are 400 to 500 metres high. Ascending them on the southern side of the river, one attains at 1200 or 1300 metres above the sea a mountain spur, which is one of several that jut outwards toward the canyon from the higher mountains and that are separated by the deep ravines of the lateral streams. North of the Calenfu is the Cerro Repollo, which attains an elevation of 2260 metres and has several other peaks that reach 2200 metres. From these summits there is an abrupt descent of 300 or 400 metres and then a long gentle slope by which the surface is carried down to the spurs that jut into the canyon. Looking westward the eye may see many spurs, one beyond another and each one so related to the others in form and slope as to represent a former surface that extended up the valley to the remoter summits in the western part of the Cordillera, 20 or 30 kilometres distant. The surface is now discontinuous because more recent canyons and ravines have been eroded in it, but it was formerly continuous, as is proved by the longitudinal and transverse profiles of the ancient valley of erosion.

Turning in the opposite direction and looking eastward, the old surface of erosion may be traced downstream to the point where it issues from the mountains east of the Cerro Renollo. There it passes into the surface of gravel deposits, which correspond with the alluvial cone of the old valley and cap the eastern mesas. The underlying mass of the mesas consists of late Tertiary tuffs that accumulated in the depression east of the range nearly or quite up to the time of deposition of the capping gravels. The gravel plain is an extensive one, being formed of the confluent deposits carried out by the various streams which in Pliocene time built their alluvial cones east of the main range. Its surface is now 300 or 400 metres above the beds of the streams, which, like the Caleufu, have sunk their canyons deeply in the old valley floors of the Cordillera and in the mesa east of the range.

Some 30 kilometres southwest of the locality which has just been described, Lago Traful lies deep in the mountain mass of the Central Cordillera. The elevation of the lake is 800 metres above sea. The mountain summits both north and south of it rise to 1800 and 2000 metres, and at elevations ranging from 1500 metres up there are gentle slopes which are covered with loose detritus and a certain amount of soil, and which extend to the abrupt steeps and precipices that overlook the lake. North of the lake some of the flat-topped summits are formed of horizontally bedded lava flows, and are obviously not features of erosion, but others are cut across metamorphic rocks and granite in a way which excludes any other interpretation than that of an erosion surface in a stage of advanced maturity. The agents which are now most active are frost and wind. The slope is too gentle to be consistent with the present altitude of the surfaces above the streams and the activity of the agents now at work. On the other hand the character, altitude and generic relations of the surface are in every way consistent with the conditions of mature erosion, such as distinguished the ancient valley of the Caleufu.

The western crest of the Cordillera west of the head of Lago Nahuel Huapi, about in latitude 40° 40′, is a broad flat range. It is crossed by trails in the Mirador and Puyehue passes. The summits of the passes themselves are between 1400 and 1500 metres above sea. Beyond them on the Chilean side there are extensive meadows having a general altitude of 1200 metres and ending in abrupt slopes which descend to the Rio Golgol. The underlying rock is chiefly granite, and the surface sculptured upon it is one of ancient and mature erosion like those which have been described. This last named locality lies near the western margin of the plateau of the Cordillera and nearly 100 kilometres from the Rio Caleufu, whereas the similar surfaces in the vicinity of Lago Traful are intermediate between the two. There is no question in the mind of the writer but that these relations demonstrate the former extension and continuity of a surface of mature erosion across the entire Cordillera de los Andes.

Mount Tronador, south of the region just described, is a volcanic peak composed of flows of andesite which rest upon a granite basement; the summit of the peak is now 3,640 metres above sea. The surface of the granite basement is from 1,600 to 2,000 metres above sea. The lava fills ancient valleys in the granite, and we may observe the relation of the mature topographic surface to the lavas of the volcano which was built upon it. The actual height of Tronador as a volcano is not far from 1,500 metres, but the granite platform upon which it was built has been raised some 2,000 metres since eruptions ceased. There are other instances of volcanic eruptions whose lavas have been spread upon this old surface. Such volcanoes are the Cerro Chapelco (2,433 metres), the Cerro Azul (2,460 metres), the Meseta Alta (2,100 metres), and Cerro Repollo, all of which form a group southeast of San Martin de los Andes, in latitude 40° 15′. Another case is that of the flat-topped mesa north of Lago Traful, which has already been mentioned. One which the writer has seen only from a distance, but which appeared to present the same characteristics of a lava platform built upon an old topographic surface of moderate slope, has received the descriptive name of Cerro Plataforma. It is a summit about 2,000 metres in altitude overlooking the Rio Turbio in latitude 42° 20′, and immediately connected with it are several conical peaks, which rise to 2,500 or 2,600 metres above sea, and are presumably the old volcanic vents.

Once the ancient mature surface of erosion had been distinctly identified, and the fact of its existence had been adequately demonstrated in the localities already described, it was found to be a general feature of the southern Andes throughout the entire region traversed by the writer, from latitude 39° 40′ to latitude 43°. The same characteristics were seen to the north and to the south of these limits, and may be traced in the maps of the Comisión de Limites all the way to Tierra del Fuego. Thus the observations establish the fact that in a pre-Pleistocene, probably Pliocene epoch, the site of the Andes between latitudes 39° and 44° presented a surface which had attained a stage of mature erosion and exhibited a relief of 500 metres, more or less, above the valleys. It was diversified by volcanoes very much like those which now rise in the valley of southern Chile and in all topographic aspects must have closely resembled that low land. Since it is clear that the stage of maturity with wide valleys and gentle slopes could not have been developed except at a moderate elevation above sea, it follows that the Andes were not then the conspicuous mountain range which they have since become. Nevertheless they formed the divide between the waters flowing respectively to the Atlantic and to the Pacific, and we shall have occasion to note the original relations of the watersheds and the changes of position which have resulted from elevation and also from glacial damming.

CANYON STAGE (n + 2) CYCLE, PRE-PLEISTOCENE.

In all parts of the southern Andes the excavation of deep canyons is the most striking feature of the topography of the range. In some instances the canyons are eccentric and are due to local diversions of the rivers to which they belong, but in general they are sunk in the valleys of the old Pliocene surface. This is shown by the fact that the canyons follow the courses of the old valleys and receive tributaries from the same laterals in such manner that the drainage basins of the earlier and later stages of development remain essentially identical.

The existence of the canyons and their correspondence with the old valleys are proofs that they are due to stream erosion and that the corrading power of the streams was increased in such manner that they cut down vertically to a depth of 300 to 500 metres in the rock masses of their previous valley floors. The phenomena of canyon-cutting is of general occurrence throughout Patagonia, being a feature of the plateau or Pampa region as well as of the Andes. The depth to which the canyons have been sunk in the time which has elapsed since canyon-cutting began is directly related to the altitude of the valley floor above the local or the general base-level, and is inversely as the distance by the course of the stream from the locus of corrasion to the nearest site of aggradation. Since the altitude and the distance determine the general grade, we may express the relation by stating that the depth of canyon-cutting in a given time, or the rate of canyon-cutting, is proportional to the grade of the stream, other factors being equal.

The mature topography which characterized the Andes before the canyons were corraded was consistent only with moderate altitude above base-level. The Pampa region also was low. In the elevation which followed, the Andean belt apparently was raised to the altitude which it now has, and the Pampas were warped up unequally. In general their surface was raised highest in the western part and declined toward the Atlantic. Between the Andes and the Pampas a belt that we have designated as the pre-Andean depression[1] remained lower than either zone beside it. These differences of elevation were all established by warping and the higher or lower areas were connected by flexures, not by faulted surfaces, so far as we yet know. Within the Andes the elevation was accompanied by longitudinal normal faulting. Transverse faulting has not been recognized.

Since streams attack their upper watersheds more vigorously as they sink their channels, and grow accordingly into neighbouring watersheds of streams still flowing at higher levels, it follows that steep grade means receding divide and capture in favour of the stream having the quickest fall. It is also well established that the rate of corrasion by any stream is a function of its volume: the greater the volume the more rapid the canyon-cutting. These principles find an application in the Andes, especially to the capture of Atlantic streams which have been diverted across the Western Cordillera; we cannot, however, understand the conditions until we have in mind the form of the surface which resulted from changes of elevation.

We must conceive the progress of elevation to have been gradual. It was not a sudden or a violent movement. In consequence of it the streams which were flowing in broad valleys among hills and low divides were affected in their grades. Some were given steeper slopes and were quickened in their flow on the corresponding stretch. Others were warped to gentler inclinations and were checked in their current. Since the swiftness of the current determines the rate of vertical corrasion, those streams which were quickened

[1] "Sub-andine" zone of QUENSEL. Op. cit.

became better able to cut canyons, whereas those which were retarded became less so. There were all degrees of efficiency developed as the elevation increased. The rate of corrasion according to which the canyons developed on the steep flexure toward the Pacific no doubt came to exceed the rate of uplift, and the canyon profiles sank low in the rising mass. But the valleys of the retarded Atlantic streams were deepened but little or not at all and were raised with the broad surface of which they were features. They thus came to occupy high levels.

A section across the Andes in latitude 41° 30′ may be correctly represented as in the subjoined diagram. The width of the range is about 100 kilometres and its height above sea two kilometres. The distribution of nearly uniform altitudes from side to side shows that it was flat on top. In this section it is broken by one normal fault, which corresponds with the central valley and divides the Cordillera into Eastern and Western portions. On each of the two flanks the surface was flexed into a monocline by which the flat plateau-like summit was connected with the lower surfaces on either side. The descent on the western slope is 2,000 metres, that on the eastern into the pre-Andean depression is but 600 to 800 metres.

With the facts of altitude and form in mind, we may return to the study of the streams and of the evolution of their present courses from those which they had on the mature (Pliocene?) surface before it was warped up. In doing so we shall distinguish the effects of retrogressive erosion which we attribute to capture during the canyon stage (n + 2) from those occasioned by glaciation during later stages.

There are five rivers which rise in the section of the Andes under consideration and flow to the Atlantic: the Collonecurá, the Limay, the Pichileufu, the Chubut, and the Tecka. The Collonecurá is the northern. It drains all the Cordillera north of Lago Nahuel Huapi and Lago Traful, and receives eight considerable tributaries that head on the western margin of the Andean plateau and flow eastward across it. It has lost one tributary, the river of Lago Lacar, which now flows to the Pacific. The Rio Limay drains the basins of Lago Nahuel Huapi and Lago Traful. It formerly received the river which flowed through the Mascardi-Gutierrez canyon, but that stream was diverted to the Manso by glacial interference.

We may note that the Collonecurá and Limay head in that part of the Andes which is separated from the Pacific by the valley of Chile, and also that the channel of the Collonecurá is so low that its tributaries have a fall not notably less than that of the opposing rivers on the western slope. It is also notable that there are no very decided displacements by normal faulting in this northern section of the area, and that in this respect it contrasts with the southern section. These facts explain the absence of captures (the Lacar excepted) by Pacific streams.

The Pichileufu, the Chubut, and the Tecka now rise in the Eastern Cordillera, which is the continental divide, yet the continuity of that divide is broken by several deep wind-gaps, which represent the valleys of streams that formerly flowed across it and were the headwaters of these rivers. The wind-gaps are due to diversion of those headwaters, first as a result of normal faulting, and later because of the greater fall and volume of the rivers that flowed to the Pacific. Near the latitude of 41° 30′ is the wind-gap of the Paso Villegas (1,314 metres above sea), now the divide between the Rio Villegas and the Arroyo Pichileufu. Next, near latitude 41° 40′, is the Paso Valle Grande (1,050 metres), a broad valley between minor tributaries. Another (1,170 metres) occurs near 41° 50′. Near 42° is the broad flat pass (805 metres) between the Quemquemtreu and the Arroyo Maiten. Between 42° 10′ and 42° 20′ is the much wider pass of Cholila (formerly about 800 metres above sea) between the Rio Chubut and the Rio Epuyen. All of these wind-gaps have a common history. They are clearly old river channels, all formerly occupied by Atlantic streams, where now there is the continental divide.

In the process of elevation the normal fault, which now bounds the central valley along its eastern side from the Rio Villegas, latitude 41° 25′, to the Epuyen, latitude 42° 10′, developed across the courses of the Atlantic rivers at right angles to them and broke the streams in two. Their headwaters formed a river which ran southward in the central valley along the downthrown block and issued by the lowest pass, that of Cholila, to the Chubut. The indication of this fact is found in the direction of longitudinal slope of the fault block and the degree of development of the wind-gaps, which culminate in the Cholila pass.

One effect of these diversions to the central valley and Rio Chubut was to increase the latter and diminish the river that formerly flowed through the Paso de Apichig (latitude 41° 55′), so that the Chubut captured the Apichig stream and left the remarkable wind-gap of that pass.

Another effect was to develop the central valley, by extending its watershed to the east and west by the growth of the tributaries, which had gained a new and lower local level of discharge in consequence of the sinking of the fault block. They fixed the passes on the Eastern and Western Cordillera nearly as they now exist, leaving sections of the old valleys which we recognize in the wide flats that saddle the mountain ridges. The Villegas, the Foyel, and Quemquemtreu on the east; the Lake Martin-Steffen river, the Rio Leon-Arroyo-Seco-Manso valley, the Lago Escondido stream, and the Azul from the west, all joined in the central longitudinal valley and flowed south and east by the Cholila pass to the Chubut and the Atlantic. The level of that valley along the Bolson and the Hoyo de Epuyen was much higher than now, probably 800 to 900 metres above sea.

The continental divide was still on the Western Cordillera. It had been pushed westward by the growth of the western tributaries of the central valley, in consequence of the acceleration initially given those streams by the elevation of the Western Cordillera above the downthrown fault-block, and the Atlantic drainage probably had encroached upon the Pacific. We see this in the flat passes that represent the former valleys of rivers that are believed to have flowed westward. It may be, however, that they flowed eastward and that the divide, having originally lain to the west of its present position, was shifted eastward, even from the beginning of the changes due to uplift.

Whether the central valley was or was not successful in contest with Pacific streams during an early stage of its development, it could not continue so at all points of attack along the divide. It was at the disadvantage of being 800 to 900 metres above sea, without any possibility of attaining a lower level on account of the long course and gentle grade to the Atlantic, whereas the Pacific streams had a short course and steep grade on which to cut. Furthermore, they were favoured by the more copious precipitation on the western slope, and that advantage probably grew with the increase in precipitation that we suppose to have led up to glaciation.

We must bear in mind also the fact that the divides of the $(n + 1)$ (Pliocene?) stage were not pronounced, as they now are, and their positions were not defined by the present elevations, that are due to subsequent uplift.

The capture of the Rio Leon, Rio Villegas and Rio Foyel, together with the Lago Martin-Steffen river, by the Manso, may first engage our attention. The course of the Rio Leon indicates that it was a tributary of the central valley. The abrupt right angle turn from southeast to southwest (latitude 41° 30′, longitude 71° 52′) shows where the Manso reached it near the Paso Cochamó. At the moment of capture the valley of the Rio Leon at that point could not have been less than 900 metres above sea, whereas the Rio Manso must have sunk its canyon much lower on account of the short course to sea-level. The conditions of the initial capture are obvious and led to the river gorge at the Paso Cochamó. The reversed stream in the lower valley of the Leon (now the Manso valley west and south of Cerro Bastion) grew eastwards into the central valley and diverted the various rivers which now form the Manso about 41° 35′. The connection of Lago Steffen with Lago Hess did not then exist, and the streams north of 41° 25′ still flowed to Lago Nahuel Huapi.

The diversion thus described relates to the waters of the northern part of the central valley through the Paso Cochamó to the Pacific. Another capture affected the southern section of the central valley. The Rio Puelo attacked the Quemquemtreu and Rio Turbio drainages through the pass of Lago Inferior, and was successful, because the Atlantic streams were retarded in consequence of the normal faulting that bounds the Bolson on the east. The earlier arrangement of rivers, as it is now inferred from the old valleys which carried their floors high above the present ones, led to the junction of the Rio Quemquemtreu with the Rio Turbio near the eastern end of Lago Epuyen (lat. 41° 13′, long. 71° 25′). The Quemquemtreu flowed to the junction by the valley of Rio Epuyen, and the Rio Turbio took its course by the valley of Lago Epuyen. The normal fault crossed both of these courses and the upthrown block on the east checked the rivers. It may have dammed them, but if so we should find lake deposits to correspond, and although there are certain strata in the valley between El Bolson and the Hoyo de Epuyen which might be so interpreted, they are more probably sediments of a glacial lake. The retarded rivers could not in any case escape capture by the Rio Puelo, which had the advantage of rapid fall on the rainy slope of the Cordillera. The Puelo grew through the divide by Lago Inferior and diverted the Turbio. The connection between that stream and the Quemquemtreu along the valley of the Bolson followed speedily, for the valley was already traced by the faulting and was floored by soft sediments (Patagonian) in contrast to the granites on either side. As the Rio Puelo deepened the diversion canyon, the inverted streams grew eastward, and the continental divide became fixed on the Eastern Cordillera, probably on the heights encircling Lago Epuyen. The waters of the Lago Epuyen watershed still flowed to the Atlantic. We shall see that glaciation subsequently built a moraine across the Cholila pass and established a lake basin which found an outlet to the Hoyo de Epuyen by the canyon now followed by the Rio Epuyen.

The next capture of Atlantic by Pacific waters which we encounter as we go south, is marked by the gorge of the Ftaleufu, or Great river, in latitude 43° 20′. It is a far-reaching one and its effects have been modified by subsequent glacial diversions also. On the east of the Cordillera in this latitude the Rio Teeka flows north to join the Chubut in its course to the Atlantic. Its valley is parallel to and not far from the continental divide, which is interrupted by several wind-gaps, the channels of streams that formerly were tributary to the Teeka. The earlier drainage, that of the (n+1) stage, comprised three principal rivers, which flowed east to the Teeka by the passes of Esquel, Sunica Paria, and Lago Rosario. The Esguel pass being particularly wide and deep it is probable that the river flowing through it persisted longer than the others and may have captured them by a branch which joined it in what is now the valley of the Rio Percey, in latitude 43°, longitude 71° 28′, and grew southward along the zone 0f soft Tertiary sandstone. ℲI us call this river the Rio Esguel. The northwest branch of the Rio Esguel was the Lago Menendez-Ftalaufquen system, which then followed southeast to the junction in the Percey Valley east of Cordon Situacion.

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After the development of the southern branch the Rio Esguel received the waters that followed the valley of the present Ftaleufu running northeast instead of southwest. Its head was probably near lat. 43° 25′, long. 72° 06′, but it can not be fixed, unless by the sharp bend of the river. The valleys were high above those of the present time, although in the (n + 1) stage probably not so high above the sea.

In course of elevation of the Cordillera the Andean plateau in this latitude was broken by two normal faults which bound a central sunken valley, or graben, that did not share in the elevation of the eastern and western sections. The junction of the northwest and southwest branches of the old Rio Esguel was in this graben, and the lower course of the main river lay across the uprising block on the east. The river was accordingly checked in that direction. The two branches, on the other hand, heading in the rising block on the west, must have been accelerated. In competition with the Pacific streams they may have extended their watersheds, but as their local base-level was high above sea-level they could not corrade their valleys as deeply and were liable at some point to capture from the west. The successful attack was made at the head of the southwest branch of the Rio Esguel and resulted in the canyon, which grew headwards, northeastward and eastward down the former valley of the southwest branch until, having reached across the Western Cordillera it extended into the graben beyond the western fault. There, in lat. 43° 09′, long. 71° 31′, it diverted the tributary which now corresponds with the lakes from Lago Situación to Lago 3.

Further captures followed readily for the graben was floored with soft sandstones (Patagonian) and the augmented volume of the river corraded the canyon deeply in the Western Cordillera. We see these effects in that very deep and narrow gorge by which the Ftaleufu flows from the Valley of 16 de Octubre to Lago Yelcho. The diversion extended to the northwest branch, that of the Lago Menendez-Ftalaufquen river, and also, by what is now the gorge of the Rio Corrintos, reached across the Eastern Cordillera to the headwaters of that river, which was captured at Sunica Paria and taken from the Rio Tecka. A consequent stream, the Rio Percy, grew in the graben, and the Arroyo Esguel remained as the inverted section of the former old Rio Esguel, that had ceased to exist as an Atlantic tributary.

The northwest branch, the Lago Menendez-Ftalaufquen system, gained additional watershed by the capture of the valley of Lago Rivadavia and the Rio Cholila, including Lago Cholila. The Pliocene (?) river in that valley had two head branches, which rose in the Western Cordillera, and flowing eastward and northeastward, met in lat. 42° 30′, long. 71° 30′, whence they continued northeastward in the Lago Mosquito valley, through the pass north of the Cordon Leleque to the Chubut. This river was retarded by the uplift of the Cordon Leleque, which checked its lower course, and by the downthrow of its valley along the normal fault that skirts Lago Rivadavia and may have originated that branch of the river. Thus checked, the stream was captured by a tributary of the Lago Ftalaufquen river which, having been diverted to the Pacific drainage by the Ftaleufu, had gained a lower, advantageous position. The channel of the Ftaleufu was more than 500 metres above sea, its present altitude, for it has since been materially deepened; but the Rivadavia-Cholila river was held above 750 metres, the altitude of the pass in the Cordon Leleque, and was subject to capture from the lower, accelerated stream. The river was reversed by headwater attack and the drainage took the course which it now has—southwestward in place of northeastward.

The Ftaleufu thus acquired by stream capture, due to advantage of fall and volume, the entire drainage of the Cordillera south of the high range which in latitude 42° 20′ extends across the Andean plateau from the Pacific to Cordon Cholila, and is dominated by the Pliocene (?) volcanoes of Cerro Tres Picos (2,500 to 2,600 metres.). On the south the Ftaleufu at this stage received the Rio Hielo-Rio Frio waters, which were subsequently diverted to the Rio Corcovado by glacial damming.

Next south of the Rio Ftaleufu, the Rio Palena or Carrenleufu flows entirely across the Cordillera and enters the Pacific. The name of the upper portion of this stream is the Rio Corcovado (the Hunchback), which is peculiarly appropriate because of its crooked course. It rises in Lago General Paz and flows northeastward to lat. 43° 50′, long. 71° 10′; thence its course is northwestward and finally southwestward. At the first bend from the northeastern to the northwestern course, the waters have been diverted from their previous route to the Atlantic by way of the Rio Tecka, of which the whole watershed of Lago General Paz was formerly the headwaters. The writer has not seen this locality, but from the observations of Mr. PEMBERTON and from the descriptions of the region, it would appear that the present divide between the Corcovado and the Tecka is a glacial dam like that which exists in the Cholila basin between the Rio Epuyen and the Chubut. Here, therefore, the latest cause of stream adjustment is glacial interference.

The course of the Corcovado northwest and southwest is along the ancient valley by which the waters formerly flowed in the opposite direction, and the canyon by which they finally pass through the Western Cordillera to the Pacific is the deep gorge that resulted from the retrogressive action of the Pacific stream in consequence of elevation. If we examine the general map we see that the Andean plateau is here deeply incised by canyons which carry a level of only 40 metres above sea into the very foot of the Western Cordillera, and give the Rio Palen in Chile an extraordinarily abrupt fall. The effect of this abrupt descent was to give the Rio Palen the necessary advantage for direct capture of the Rio Corcovado by retrogressive corrasion into the watershed of the latter, and thus the canyon across the Western Cordillera was established and the waters of the Corcovado were reversed in their own original valley.

The Corcovado now receives from the north the Rio Hielo and the Rio Frio, which reach it through a straight and narrow canyon that crosses the former divide between the Corcovado and the Ftaleufu. The diversion of these streams from the Ftaleufu to the Corcovado was a later result of glacial interference.

We have thus traced the changes and drainage which resulted in the transfer of the headwaters of Atlantic streams to tributaries of the Pacific, in the cases of the Rio Manso, the Rio Puelo, the Ftaleufu, and the Palen or Corcovado. Our studies do not extend farther south and it would be unwise to generalize as to the conditions which facilitated the captures beyond the region we have examined, since it is evident that local conditions have in each case had a marked influence. But the cases that have been described are sufficient to show that fall and volume, both of which were in favour of the Pacific streams, were determining factors. It also appears that three of the diverted rivers were retarded in their course to the Atlantic by normal faulting which developed during the uplift, and thus in those cases a special condition was introduced which rendered them less competent to cope with the attack of the Pacific streams than they might otherwise have been. In the case of the Corcovado we do not know that normal faulting had any influence, as the faults which determined the graben of the Valley of the 16th de Octubre die out southward into general flexures and are not recognized across the Corcovado. In that case the very abrupt descent to the Pacific appears to have been sufficient to have determined the diversion. While normal faulting was undoubtedly an important factor in accelerating the diversion of the other three streams, it seems probable that their capture would have been effected in favour of the Pacific, though at a later date, even if the faulting had not retarded the Atlantic streams.

It is desirable to make clear the argument for recognizing the development of the canyons that cross the Western Cordillera as results of stream erosion rather than of glacial erosion. In the preceding discussion the effect of the streams in retrogressive corrasion leading to capture is attributed to well established processes under normal and favourable conditions of such activity. Given the condition of increasing elevation of the Andean plateau with reference to sea-level, and the relative distances from the Pacific and Atlantic, the encroachment of the streams flowing down the steeper slope was a necessary, an inevitable consequence. The canyons thus established have a specific character; they are deep and narrow rock-bound gorges, which are related to older valleys and adapt themselves to the courses that rivers would naturally take in developing the inverted drainage systems. Thus the activity of the streams in effecting the diversions appears to be perfectly normal. It is otherwise with any attempt to explain these same diversions through the Western Cordillera as effects of glacial erosion, and the attempt to do so appears to have resulted only from observation of the clearly defined cases of glacial damming and interference that occur in the Eastern Cordillera. But in the Western Cordillera there is no opportunity for glacial damming by which the rivers might have been forced over the passes to the Pacific, nor is it possible that glaciers rising on the Western Cordillera (where, by reason of the greater precipitation, they naturally grew) should have cut their way through the divides in the same range. In discussing the lake basins as features of glacial erosion there will be occasion to consider the conditions under which glaciers do excavate. They are those of great pressure due to head of ice and of confinement in deep canyons. These conditions could not exist in advance of the excavation of the canyons by streams, and it is therefore a *sine qua non* of glacial erosion that there should have been profound corrasion by the rivers of the mountain range.

Thus when we consider the transfer of the drainage to the Pacific from the point of view of stream activity, we find it a normal, logical result, whereas, regarded solely as the work of glaciers, it is abnormal and inexplicable.

In passing to the consideration of the next physiographic stage we leave the question of the diversion of the drainage of Lago Lacar, a former tributary of the Rio Collencurá in latitude 40°, to be taken up under that section, as one in which the argument for glacial erosion may perhaps be considered to have the greatest validity, although the writer believes that in that case also the diversion was by stream activity.

EARLY GLACIAL EPOCH (n + 3) CYCLE.

It is evident from the changes described in the preceding paragraphs, that the canyon stage was one of prolonged duration. The uplift of the plateau of the Andes was undoubtedly gradual and the development of the canyons corresponded with the elevation. The result, as we have seen, was the transfer of a notable propo'tion of the original Atlantic drainage to the Pacific, under conditions of ordinary stream activity. The changes involved nothing more than the usual processes of erosion in a temperate climate. After the range had attained an altitude which apparently must have been very nearly, if not quite, that which it now has, a climatic change resulted in the development of extensive Cordilleran glaciers.

The term climatic change is here used to distinguish the variation in temperature and precipitation which occasioned glaciation, from the effect of altitude that had not been adequate to produce extensive glaciers during the canyon-cutting stage. It is evident that there was a long epoch during which the Andes had nearly or quite their present elevation, yet did not develop glaciers adequate to fill the canyons, as they did later on. When glaciation did become extensive the general temperature must have been somewhat lower than now, since at present the glaciers in latitudes 40° to 41°, on peaks that do not rise above the common altitude of 2,000 metres, are insignificant. The causes of the lowered temperature are not determined by these facts, but elevation of the range is excluded from consideration as one of the causes by the recognition of the antecedent epoch of high altitudes without glaciers.

We do not know whether the inception of this glaciation in the southern hemisphere corresponded closely with the beginning of glaciation in the northern hemisphere or lagged behind the latter, and we are therefore unable to say whether the canyon stage should be assigned to the pre-Pleistocene or to the Pleistocene. But in discussing the earliest glaciation of the Southern Cordillera we are no doubt dealing with Pleistocene phenomena.

It is not yet well established whether or no the "early" Glacial epoch, of which extensive and unquestionable evidences remain, was the earliest. In the vicinity of San Martin de los Andes, Prof. R. D. SALISBURY recognized a till, which by its induration, disturbed position, and relation to certain lava flows from the local volcanic centre, appears to be older than the moraines of that glaciation to which the title of "early" had been given. At the outlet of Lago Fonck, in latitude 41° 20′, the stream forms a cascade over an indurated till, which is possibly older than the widespread early Glacial deposits of that basin. These indications, together with the fact that three epochs of glaciation are recognized on the Pacific coast of North America, suffice to make it probable that the "early" was not the earliest glaciation in Patagonia; but the effects of any older glaciers were like those of that epoch and have been to a great extent obliterated by them.

The evidence of an early Glacial epoch is varied and abundant. East of each of the larger valleys of the Andes we find moraines of great volume and altitude. Associated with them are all of the allied features characteristic of glacial deposits. They are entirely distinct in position from the latest moraines, from which they are sometimes widely separated, as the early glaciation was more extensive than the latest. Furthermore, the degree of erosion which the older glacial deposits have suffered and the decomposition of the granite boulders which they include are such that their antiquity is firmly established. As WELLINGTON JONES and SALISBURY have made a special study of the glacial deposits they will not be described in detail in this connection. The description will be limited to effects of erosion and of interference with the streams.

The most notable effect of the early glaciation was the excavation of the lake basins, which transformed many of the canyons of the canyon stage into very deep lakes. It is not necessary to enumerate the lakes. They are the most conspicuous features of the map of the southern Andes. Their coincidence with the former valleys and canyons is equally evident when one studies the distribution of the glacial deposits. The only debatable point is the mooted question of the ability of glaciers to erode. Those who are familiar only with areas in which glaciers have laid down deposits or who have seen the ice riding over moraines of loose gravel without eroding it, maintain that glaciers do not erode, and under those conditions of free movement they do not. But, as GILBERT has pointed out, a glacier is a tool which, like a river, works differently under different circumstances. Rivers do not erode in their flood plains, neither do glaciers; but, having adequate fall, rivers do excavate canyons, and glaciers, when the ice is confined and under the pressure of a high head, widen and deepen the canyons which the rivers have previously corraded.

The glaciers of the Cordillera originated in the amphitheatres between 1,500 and 2,000 metres above sea, and were conducted by the converging channels of the various minor canyons into the main canyon of each drainage system. Owing to the earlier development of these rivers, they had far-reaching headwaters and deep narrow channels below. The effect was to concentrate in the latter an enormous volume of ice, which was crowded forward under a head of from 500 to 1,000 metres. Under these conditions the corrading effect of the rock-laden ice masses was very great. The canyons were deeply excavated far below the sills of their outlets, and upon the retreat of the glaciers were left as rock-bound basins.

It appears upon inspection of the map that there is a direct relation between the extent of the watersheds (or glacier-sheds) and the size of the lake basins which the ice produced. If we had the data, it would no doubt be shown that the depth of the basins is directly as the head and volume of the ice, due consideration being given to the narrowness of the gorge into which the glacier was forced.

Unfortunately, we have no reliable soundings of the Andean lakes, but it is evident to anyone who coasts their precipitous shores and looks down into the blue-black water that they are exceedingly deep. In the case of Lake Chelan in the State of Washington, we know that the rock-basin is 700 feet deep below its outlet sill. There is every reason to suppose that Lago Nahuel Huapi, Lago Traful, and others of the Andean lakes are quite as deep or deeper.

Certain changes of river courses which had persisted during the canyon period are attributable to glacial interference, and give rise to some of the most interesting canyons of this region. One of the most striking is found south of Lago Nahuel Huapi in the watershed of the Rio Manso. Another occurs on the Epuyen. Still another has affected the outlet of Lago Ftalaufquen. And it is possible that the diversion of the waters of Lago Lacar is to be attributed to the same cause. We may consider some of these cases.

The Rio Manso heads on Mount Tronador, on the slopes of the old volcano, and flows southeast to Lago Mascardi in the course which it had on the Pliocene surface. Its former valley is continued in Lago Mascardi and Lago Gutierrez to Lago Nahuel Huapi. At the time of the earlier glaciation, this Pliocene (?) valley was occupied by a glacier which transformed part of it into Lago Mascardi, while the site of Lago Nahuel Huapi was occupied by a far larger glacier which excavated that great basin. Upon the retreat of the ice, that which occupied the basin of Lago Gutierrez and which presumably was confluent with that in Lago Nahuel Huapi dammed the outlet of Lago Mascardi. The waters flowing from Mount Tronador were therefore obliged to seek another channel, which they found in the old valley that connected Lago Hess and Lago Mascardi. During the earlier epochs the current had flowed eastward through this valley and had been tributary to Lago Nahuel Huapi; it was now turned westward. The basin of Lago Hess lies at an elevation of about 730 metres above sea, while that of Lago Steffen is 220 metres lower, and but 15 kilometres away. The outlet of Lago Hess is down this slope to Lago Steffen. It may have been established during the canyon stage in consequence of retrogressive erosion and capture from the lower levels; or it may be that the capture had not been completed before glaciation began. In that case a lateral stream flowing by the southwest side of a glacier which occupied the Lago Hess basin crossed the divide and began the work of deepening the canyon on the slope to Lago Steffen. The effect of these changes is that the Rio Manso adopted a zigzag course, flowing southeast from Mount Tronador, as it had done from the time the volcano was built up, but then turning westward to Lago Hess, again southeastward to Lago Steffen, and finally westward in the canyon by which the waters had been diverted to the Pacific. Thus the continental divide was established between Lago Gutierrez and Lago Mascardi across the old valley of the Pliocene tributary of Lago Nahuel Huapi.

In describing the changes of drainage which occurred during the canyon stage, reference was made to the pass at Cholila, east of Lago Epuyen, about latitude 42° 15′, through which it is believed that the drainage of the central valley of the Andes and of the Rio Turbio formerly flowed to the Chubut. The capture of that drainage through Lago Inferior and its transfer to the Pacific is attributed to the activity of the Rio Puelo, the Pacific tributary, and the usual processes of headwater corrasion. The pre-Glacial divide was probably established on Cerro Pirque and the ranges east and southwest of that peak. From it a glacier descended into the basin of Lago Epuyen, whence it spread upon the broad flat of Cholila. The moraine which it built there extends from north to south and its two ends rest upon sections of the Eastern Cordillera which carry the continental divide. That divide is therefore continuous along the summit of the moraine. It forms an arc concave toward the west, and the drainage from it falls in a sharply cut ravine to the level of Lago Epuyen, whence it discharges northwestward through a very narrow rock canyon that is part of the present channel of the Rio Epuyen. As we overlook the Cholila basin, we are struck by the very obvious lake terrace that skirts the moraine in a perfect level and which records the persistence of the former lake at a height of about 700 metres. It is at once evident that the glacier in retreating westward left a lake basin between its front and its moraine, and that the lake persisted long enough at a high altitude to develop the terrace. As the lake was apparently circular and its diametres at the highest stage were from 10 to 15 kilometres in length, the waves had sufficient fetch to do effective work. The discharge from the Cholila lake was at its northwest corner, where the glacier impinged against Cerro Pirque, across a low col of rock which lay at the head of the Rio Epuyen. In this rock col the waters cut the canyon which has been referred to above and which is 60 metres deep, with a minimum width at the bottom of about 10 metres.

The former existence of this lake basin was observed by QUENSEL, who referred to it in discussion at the Toronto meeting of the International Geological Congress, and it is one of those cases which is typical of the diversion of streams in the Eastern Cordillera. The moraine dam, the lake terrace, the canyon of the lake outlet, and the lake sediments which are exposed in the post-Glacial ravine, constitute a chain of evidence that is conclusive and can not escape observant notice. These phenomena appear to be well developed in the neighbourhood of some, if not all, of the larger lakes to the south, and it is to their existence that we may attribute immediate acceptance of the glacial origin of the stream diversions to the Pacific, but in the Cholila instance the glacial effect is secondary to the previous capture by retrogressive stream erosion, and it may reasonably be inferred that a similar condition will be found to affect the interpretation of other basins that resemble this one.

It is not clear whether the moraine at Cholila represents the early Glacial and the later Glacial as well, or only one of them. The phenomena seem almost too fresh to belong to the earlier glaciation alone, and yet the river canyon at the outlet of the lake is deeper than we would expect had it been formed since the retreat of the latest glaciers. It seems probable that effects of both glaciations may here be found superimposed one upon the other.

The diversion of the Rio Ftalaufquen in latitude 42° 50′ from its course in the valley east of Cordon Situación to the remarkable canyon west of that range, is also an effect of glaciation. The watershed tributary to Lago Ftalaufquen is both high and extensive, and the mass of ice which was concentrated in the lake was large. A great quantity of moraine material was deposited by it in the valley of the Rio Percey and, on the retreat of the ice, served as a dam to prevent the waters from pursuing their ancient course. They were held at such a level that they found an outlet through Lago Kruger across a low divide west of Cordon Situación, and so discharged into the watershed of Lago Situación. The canyon which has been cut in consequence of this diversion was one of the most inaccessible of the region. In this case there was no change in the ultimate course of the river, since the waters continued to flow to the Rio Ftaleufu as before, although by a new channel.

A case of diversion that is due to glacial damming is that of the Rio Hielo and Rio Frio, which are now tributary to the Corcovado in latitude 43° 30′, but formerly flowed to the Rio Ftaleufu, which they joined in 43° 10′. The divide between the watersheds of the Rio Frio and the Ftaleufu is composed of glacial material filling a wide valley at an altitude of about 700 metres above sea. This is higher than a pass in the divide between the same river, Rio Frio, and the Corcovado. It would thus appear that the glacial dam had forced the waters to cross the lower divide to the Corcovado either during the existence of the glacier, or as the outlet of a lake which formed as the glacier retreated. As the writer has never visited this basin, he is unable to form an opinion as to which conjecture is the more reasonable.

The glacier which occupied the basin of Lago Nahuel Huapi during the earlier epoch extended 15 kilometres beyond the present lake basin and built a terminal moraine across the valley of the Rio Limay at a point which is now know as El Gran Rincon. The waters flowing from the glacier were forced to find an outlet at one side of the valley and crossed a rocky col between the Limay and the Arroyo Fragua. Upon the retreat of the glacier this course was taken by the river itself, which therefore flows through a rocky narrows at this point.

Reference has already been made to Lago Lacar, and to the possibility that it was diverted to Pacific waters in consequence of glaciation. Lago Lacar lies in a very deep basin at an altitude of 645 metres above sea, and 200 metres below the level of the old valley, which formerly discharged eastward to the Atlantic. At the western end of the lake is a group of peaks known as the Cerro Ipela, which rises beyond 2,000 metres above sea, and is a broad region capable of discharging a very large amount of glacial ice. The depth to which the lake basin of Lago Lacar is excavated is no doubt due to this fact, the ice, which descended 1,406 metres directly into the old canyon, having been a most effective tool. The outlet of the lake is at the foot of the Cerro Ipela and towards the northwest. The origin of this outlet is an undetermined question. It is tributary to Lago Perihueco, to which there is a gradual descent. It may have been established by retrogressive erosion and capture as was the case with other rivers farther south. If we examine the plan of the river channels, without reference to the present altitudes, it is evident that the valleys of Lago Perihueco and of the Rio Lipinza unite with the common acute angle of autogenous streams and, so considered, formed the headwaters of the Rio Lacar, that flowed to the Atlantic. Their position, far to the west, rendered them liable to capture by the Riñihue at a point north of the volcano Choshuenco, where we now find the greatest fall in the river's course. The capture having been effected on the steep Pacific slope, the canyon was cut back eastward past the Ipela range and into the lower Lacar valley, with a corresponding reversal of slope in the channel. Subsequently the effects of glacial erosion widened and deepened the basins of Lacar and Peribueco, which became the lakes of the present.

As opposed to this explanation, it may be urged that the glaciers which descended from the Ipela range and excavated the rock basins of Lago Lacar and Lago Perihueco, were competent to erode the divide between the two, and did so, cutting it down to a level at which the waters of Lago Lacar flowed across it after the retreat of the early glacier in preference to resuming the eastward course, across which the glacier had built a morainal dam. In that case, the river should have cut a canyon and must have lowered the outlet during the inter-Glacial period. Then there should remain the terraces of the earlier levels of the lake in their appropriate relation to the early Glacial deposits. Upon these evidences, the latest Glacial deposits should be superimposed.

We have not been able to study this locality sufficiently to discriminate between the two hypotheses of ordinary stream capture during the canyon stage or of glacial damming. Lago Lacar is exceptional in having its outlet among the tributaries of the Colloncurá and the case is one of special interest.

INTER-GLACIAL EPOCH. (n + 4) CYCLE.

The earlier Glacial epoch was succeeded by a long interval of milder climate, during which the glaciers retreated to the highest summits of the Andes or entirely disappeared; the records are too scanty, or our observations of them too inadequate, to enable us to determine which. We observe, however, that the moraines of the earlier period have been remodeled superficially to such an extent that they no longer present distinctly the typical features of glacial topography, and the materials of which they are composed are decayed to somewhat the same degree as those of the older moraines in the United States. The lapse of time occupied by the inter-Glacial epoch is strikingly demonstrated in the district immediately east of Lago Nahuel Huapi. The earlier glacier there surrounded and rose above a high hill known as Cerro Carmen, and built its terminal moraine several kilometres east of that hill, at an elevation which leaves no doubt of the former altitude at which the ice stood around it. Cerro Carmen consists of andesitic lavas and is so situated that it is not exposed to any very effective activities of erosion. Nevertheless, the roches moutonnées which must have been developed by the glacier have entirely disappeared, and the slopes of Cerro Carmen are marked by rugged pinnacles which have been eroded from the glaciated rock masses. This could not have been done except in consequence of the lapse of a prolonged period. The subsequent glaciation did not extent so far.

LATEST GLACIAL EPOCH, (n + 5) STAGE.

In all parts of the Cordillera we meet with very fresh evidences of the recent extension of glaciers. The outlets of all of the northern lakes, including Lago Nahuel Huapi, and of many of the interior lakes of the Cordillera are determined by glacial moraines. Moraine terraces up to about 700 metres above Lago Nahuel Huapi and at high altitudes elsewhere throughout the Cordillera are of general occurrence. The diversion of minor streams in consequence of moraine dams and the existence of abandoned channels which were fed by glacial waters prove the former extension of the ice. The strongly glaciated rocks along the lake shores unequivocally support the evidence of the glacial deposits elsewhere. And all of these phenomena are as fresh as though they had been made but yesterday. The latest glaciation, however, was by no means so extensive as the earlier and has produced no profound changes in the distribution of the drainage, or in the physiographic types.

THE PRESENT, (n + 6) STAGE.

With the retreat of the latest glaciers the Andes entered upon the present stage of erosion, which in many respects resembles that now existing concurrently in the Pacific Coast ranges of North America in similar latitudes, in Switzerland, and in the Scandinavian peninsula. Designating this latest episode as the (n + 6) stage, we shall have distinguished six aspects of physiographic development since the Pliocene or Miocene. We have thus traced the history of the elevation and erosion of the range down to the present.

The outlines sketched in this paper may serve to suggest the wealth of material which awaits more detailed study, and the deep interest which will attach to a thorough analysis of all the problems, especially in the light which the study will throw upon the questions of mountain elevation and erosion.

ÜBER DEN ANTEIL DER QUARTÄREN KLIMASCHWANKUNGEN AN DER GESTALTUNG DER GEBIRGSOBERFLÄCHE IN DEM TROCKENGEBIETE DER MITTLEREN UND NÖRDLICHEN ARGENTINISCHEN ANDEN.

VON

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I.

Die argentinischen Anden sind an vielen Stellen sehr geeignet für die objektive Untersuchung des Einflusses, den die quartären Klimaschwankungen auf die Gestaltung der Oberfläche des Gebirges gehabt haben. Das liegt daran, dass sich die Anden bei ihrer meridionalen Richtung und grossen Länge durch trockene und feuchte Gebiete erstrecken. Dadurch ist es möglich, die besonderen morphologischen Merkmale einer jeden Klimaprovinz bis in die Übergangsgebiete zu verfolgen. Besonders günstig ist aber der Umstand, dass die Erscheinungen der quartären Vergletscherungen in dem trockenen Gebiete der argentinischen Anden im allgemeinen viel unbedeutender und deshalb auch einfacher sind als in den gut untersuchten Hochgebirgen der feuchten Klimaprovinz, wo sich, wie zum Beispiel in den Alpen, Formen von verschiedenem Ursprung viel mehr überdecken oder ineinander greifen.

Auf der Stockholmer Sitzung des Kongresses ist die Frage nach der Grösse der glazialen Erosion ausführlich behandelt worden; ich glaube man kann sagen, ohne ein befriedigendes Ergebnis. Man sieht klar den Widerspruch der Ansichten in den verschiedenen Aufsätzen über die glaziale Erosion und in dem Berichte über die Diskussion.

Ich hätte an dieser Diskussion teilnehmen und einige Tatsachen anführen können, die auf die Entstehung von Trogformen, wenigstens in den argentinischen Anden, einiges Licht werfen, jedenfalls aber eine objektivere Deutung erlauben, als es in den Hochgebirgen der feuchten Klimaprovinz möglich ist. Ich habe aber geschwiegen, weil es mir besser schien, erst meine Beobachtungen zu vervollständigen und namentlich genau zu prüfen, ob sich die Formen, die ich im Auge hatte, so, wie ich es vermutete, in den Gebieten, die einst vereist gewesen sind und solchen, die auch die grösseren unter den quartären Gletschern nie erreicht haben, wirklich wiederholen. Auch Formen ganz ausserhalb der Vereisungsgebiete wollte ich hiermit noch vergleichen. Ich habe deshalb gleich nach meiner Rückkehr nach Argentinien eine viermonatige Reise in die Hochkordilleren der Provinzen San Juan und Mendoza ausgeführt und auch sonst jede Gelegenheit benützt, meine Anschauungen in dieser Richtung zu vertiefen. Einige von den wichtigsten Ergebnissen möchte ich hier kurz mitteilen, in der Hoffnung, dass die Behandlung dieses Gegenstandes auch jetzt noch willkommen sei.

II.

Ein Blick auf die Übersichtskarten des in Argentinien und Chile liegenden Andenteiles zeigt, dass sich die Beschaffenheit des Gebirges ungefähr in der Mitte des Territoriums Neuquen deutlich verändert. Es beginnt hier die lange Reihe der patagonischen Seen, die meist in felsige Ufer eingebettet sind; zuerst mit einigen kleinen Vertretern, die aber schon im Nahuel Huapi bedeutende Grösse erreichen. Weiter südlich durchschneiden manche Quertäler den ganzen Wall der patagonischen Kordillere, und in einigen von diesen Furchen fliesst das Wasser, das auf der atlantischen Seite des Gebirges entspringt, zum Stillen Ozean. Mit dem Wechsel der grossen morphologischen Züge ändert sich auch das Bild der Vegetations- und der Schneedecke. Ein Gürtel von dichtem Wald stellt sich mit den ersten Seen ein. Er bekleidet zuerst nur die chilenische Seite, im südlichen Teile von Neuquen aber schon beide Abdachungen. Die Schneegrenze senkt sich rasch auf der pazifischen Seite. Sie liegt am Vulkan Osorno (41° 10′ S. Br.) in Höhe zwischen 1300 und 1400 m. In Breiten, wo in Europa die Alpen und die Pyrenäen liegen, reichen von der niedrigeren patagonischen Kordillere die Gletscher bis zu den Seen und dem Meeresniveau hinab, und auf einer Strecke von zwei oder drei Breitengraden ist die Oberfläche des Gebirges mit Inlandeis bedeckt. In diesem Abschnitte der Anden herrscht ein ausgesprochen feuchtes Klima. Den grössten Teil der Niederschläge bringen die Winterregen.

Ganz andere Verhältnisse finden sich nördlich von diesem Gebiete; von der nördlichen Ecke Neuquens bis in das Hochland von Bolivien. Das Wasser der grossen Flüsse in Neuquen erreicht zwar noch dauernd den atlantischen Ozean, aber schon etwas weiter nördlich ist der Lauf des Rio Desaguadero, der das Schmelzwasser eines fast 700 km langen Stückes der Hochanden aufnimmt, sehr oft unterbrochen. Bald darauf treffen wir, nordwärts gehend, vor dem östlichen Fusse der mittleren argentinischen Anden, auf grosse abflusslose Becken. Weite Strecken sind hier mit Dünen oder mit Salz bedeckt und die ausgedehnten Flächen der Schuttkegel in den Niederungen bekleidet nur spärlicher Busch von xerophylen Pflanzen. Hier, in den Gebirgszügen der Provinzen San Juan, La Rioja und Catamarca, herrscht der höchste Grad der Trockenheit. An vielen Stellen ist die Höhe der jährlichen Niederschläge geringer als 60 mm.

Erst an dem nordöstlichen Saume des argentinischen Andenteiles beginnt mit den grossen Wasseradern des Rio Bermejo und des Rio Pilcomayo aufs neue die marine Abdachung. Hier treffen wir auch wieder Wald.

Er bekleidet freilich nur die äusseren Gebirgszüge und reicht im Mittel nicht höher als 2000 m hinauf. Die Schneegrenze bleibt aber in grossen Höhen. Dies ist das Gebiet der excessiven Sommerregen.

Den Streifen der Winterregen im Süden, das meist abflusslose Gebiet der trockenen Klimaprovinz, das mehr als die Hälfte der Anden in Argentinien und Chile umfasst, und die verhältnismässig schmale Zone der Sommerregen im Nordosten wollen wir als die wichtigsten Klimagebiete unterscheiden.

Die zweite allgemeine Tatsache, von der wir ausgehen, ist das hohe Alter dieser verschiedenen Gebiete. Aber die Anzeichen hierfür sind viel weniger augenfällig als die Unterschiede des heutigen Bildes, die die verschiedene Verteilung der Niederschläge, namentlich durch die Vegetations- und Schneedecke, hervorruft. Viele von den geologischen und morphologischen Merkmalen, die bei genauer Prüfung und Vergleichung gerade als Zeugen der grossen Persistenz dienen, hat man im Gegenteil bisher im allgemeinen hauptsächlich als Hinterlassenschaft der doch im Ganzen rasch vorübergegangenen Klimaschwankungen betrachtet; im Gebiet der Winterregen, zum Beispiel, die Durchbruchstäler der patagonischen Kordillere als reine oder vorwiegend glaziale Erosionstäler der quartären Gletscher, im Norden die oft ausserordentlich grossen Schuttmassen des Trockengebietes, die sicher zum grössten Teil tertiäres Alter haben, als glaziale Anhäufungen und fluvioglaziale Schotter. Es ist nicht möglich, hier die verschiedenen Beweise für das hohe Alter der Klimaprovinzen in den Anden einzeln anzuführen. Aber die wenigen Tatsachen, die besprochen werden sollen, genügen schon dazu und haben allgemeine Geltung.

III.

Das Trockengebiet der argentinischen Anden unterscheidet sich in morphologischer Beziehung beträchtlich von den viel feuchteren europäischen Alpen. Seinen besonderen Charakter verleiht ihm die grosse Häufigkeit und Ausdehnung alter, ganz reifer Formen bis in die grössten Höhen und der breite Schuttgürtel, der sich zwischen die Schnee- und die Vegetationsgrenze schiebt; oder mit anderen Worten, in den Anden sind, in der Höhe, die scharfen Formen der nivalen Klimaprovinz viel weniger entwickelt und die präglazialen Formen, die als Rumpfflächen noch oft die Blockform der zerbrochenen und emporgewölbten Gebirgsstücke erkennen lassen, durch die spätere Erosion nicht so verändert und zerstört worden als in den Alpen. Ich habe auf diese Erscheinung vor einigen Jahren hingewiesen[1] und durch BOWMANS[2] Untersuchungen wissen wir, dass sich hoch gelegene Rumpfflächen in grösster Entwickelung auch im nördlichen Chile und in dem südöstlichen Teile der bolivianischen Anden finden.

Diese Rumpfflächen bilden in der Richtung ihrer grössten Ausdehnung, nämlich in der des Gebirges, manchmal auf Strecken von 50, 80 und mehr Kilometer und bis zu Meereshöhen von 5000 m, den Scheitel der Gebirgszüge.

[1] Sitz.-Ber. Ak. Wiss., Wien, 1908; Zeitschr. f. Gletscherk., 1910.
[2] Am. Journ. Sc., 1909.

Sowohl in den grossen Längstälern, die die einzelnen Züge trennen, als auch in dem Quertälern, die sie durchschnitten haben, sehen wir oft viele Felsterrassen. Sie sind manchmal so gut erhalten, dass man schon durch die einfache Beobachtung von einem gut gewählten Standpunkte den Verlauf der einzelnen Niveaus und ihre gegenseitigen Beziehungen erkennen kann.

Die Schneegrenze erreicht in den argentinischen Anden vielleicht die höchste Lage auf der ganzen Erde. Dies gilt wenigstens für die Gebirgsteile an dem östlichen Rande der Puna de Atacama, wo selbst 6000 m hohe Berge, wie der Nevado de Acay, nur einige unbedeutende Firnstreifen und Firnflecken tragen, die durch Winterschnee genährt werden. Dem entspricht die verhältnismässig unbedeutende Senkung der Firnlinie um 500 800 m während der quartären Klimaschwankungen. Aber auch dieser Betrag erscheint noch zu gross, verglichen mit den Verhältnissen in den Alpen; denn der Schnee ist durch die ständigen Westwinde von den Rumpfflächen abgetrieben und auf der Ostseite der Gebirgszüge und der hohen Berge angehäuft worden. Wir sehen dies auch heute sehr deutlich. Auf die Lage der quartären Schneegrenze können wir nur aus der Hohenlage der Moränen alter Patenngletscher, der alten Kare und den Ansatzstellen der gut erhaltenen Seitenmoränen schliessen. In der Tat trifft man in diesen Breiten auf der Westseite der hohen Gebirgszüge meist eine ausgedehnte Schuttabdachung, auf ihrer Höhe die schneefreie Rumpffläche oder Reste davon, und auf ihrer Ostseite eine Anzahl nebeneinander liegender, eisfreier Kare, die nach oben mehr oder weniger in derselben Höhe abschneiden.

Gegen Süden und Osten senkt sich die heutige Schneegrenze. Sie liegt aber auch hier noch sehr hoch. In dem Teile der Hauptkordillere der Provinz Mendoza und in den Gebirgszügen der Provinz Salta, nahe an der Niederung des Gran Chaco, die wir noch etwas eingehender betrachten werden, liegt sie noch immer in Höhen um 5000 m. In diesen Richtungen nimmt auch der Betrag der quartären Senkung der Schneegrenze etwas zu; aber nicht in dem Masse, dass der bestimmte Charakter des Trockengebietes in der Zeit der alten Vereisungen, auch nur vorübergehend, verwischt worden wäre.

Ich kann hier nicht bei Einzelheiten verweilen. Wenn ich aber alles zusammenfasse, was ich über die morphologische Gliederung der Gebirgsoberfläche in der trockenen Klimaprovinz und den Anteil der quartären Klimaschwankungen daran weiss, so möchte ich drei verschiedene Gebiete unterscheiden, nämlich: (1) das Gebiet, wo das Klima immer so trocken war, dass Gebirgszüge über 5000 m Meereshöhe auch während der Klimaschwankungen keine Gletscher trugen, (2) das Gebiet, wo grössere Talgletscher entstanden sind und sich in kleinen Massen auch heute noch finden, und (3) das Gebiet, in der Regel unter 4000 m Höhe, das zwar nicht vergletschert war, aber den Einfluss der Klimaschwankungen in grösserem Maasse in anderen Wirkungen erkennen lässt.

Das erste, ausserordentlich trockene Gebiet umfasst einige zerstreute Erhebungen in dem östlichen Teile der Puna de Atacama und der Hauptkordillere in den Provinzen La Rioja und San Juan. Hier findet sich über der Höhenlinie, bis zu der hinab in den Sommermonaten der Schnee fällt, in rund 4000 m. Höhe, ein fast ununterbrochener Schuttmantel, der beinahe ganz frei von Vegetation ist, alle Umrisse rundet und nur die alten Formen der fluviatilen Erosion durchschimmern lässt. Ich nenne es das *Punagebiet.*

Das zweite Gebiet, das der alten Talgletscher, das auch heute noch vereist ist, zeigt Kare und andere Formen, die für die Firnregion kennzeichnend sind. Es finden sich permanente Wasserläufe, und alte Moränen füllen tief hinab die Täler. Auf ihnen wächst eine verhältnismässig dichte Strauch- und Grasvegetation. Diesen Gürtel, der hauptsächlich zwischen 4000 und 5000 m liegt und in seinen höchsten Teilen dem alpinen Hochgebirge ähnlich wird, nenne ich das *andine Gebiet.* Es umfasst einen langen Streifen der Hauptkordillere in Chile und den argentinischen Provinzen Mendoza und San Juan und einige vereinzelte Gebirgszüge weiter nördlich.

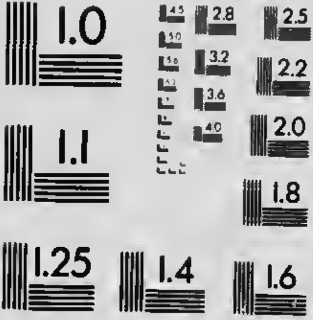
Das dritte Gebiet, das nie vergletschert war, treffen wir in guter Ausbildung vor allem in den zerstreuten Erhebungen vor dem östlichen Fusse des Gebirges und in seinen Randketten. Es liegt im allgemeinen unter 4000 m Höhe. Hier finden sich vorherrschend junge felsige Formen oder Mittelgebirgsformen. Namentlich in den Quertälern, die oft tiefe unausgeglichene Furchen sind, haben sich unter der Einwirkung der Klimaschwankungen grosse Mengen von Schutt, fluviatilen Schottern und fluviatilem Loess angehäuft. Der untere Teil der Gehänge ist mit dichtem Wald oder Busch bedeckt. Bis an die obere Grenze dieses Gürtels reicht die Vegetation in der Form der alpinen Grassteppe. Dieses Gebiet, das sich ziemlich genau mit dem der Sommerregen deckt und nur nach Süden etwas über dessen heutige Grenzen hinausreicht, nenne ich das *pampine Gebiet.*

In dem nördlichen Teile der argentinischen Anden berühren sich das Punagebiet und das pampine Gebiet auf einer langen Strecke. Der andine Gürtel ist hier nur sehr wenig entwickelt. In dem mittleren Abschnitt des trockenen Gebirgsteiles verschmälert sich das Punagebiet, und an seine Stelle tritt, in immer breiterer Entwickelung, das andine Gebiet, das schliesslich südlich vom Rio de Mendoza bis an den Rand der Anden reicht. Die drei Gebiete gehen allmählich in einander über, und es kann der Fall eintreten, dass in derselben Höhe, mit der Zunahme der Trockenheit, die östliche Seite eines Gebirgszuges die Formen des andinen Gürtels zeigt, die westliche Abdachung aber in reiner Ausbildung die Kennzeichen des Punagebietes; oder die Moränen der alten Talgletscher reichen bis in das pampine Gebiet hinab. Dennoch haben wir drei Gürtel von Formen, die sich in wesentlichen Zügen unterscheiden.

Nun ist es auffallend, dass sich in ihnen die alten Rumpfflächen auf der Höhe und an den äusseren Gehängen der Gebirgszüge und die Felsterrassen in den Tälern durch die ganze Trockenzone immer wiederholen. Dies ist eben der Ausdruck zweier allgemeiner Tatsachen, nämlich: (1) dass sich die alten, ganz reifen Formen, auch wenn sie durch Bewegungen wieder in den Bereich der Abtragung gekommen sind, unter den Bedingungen des persistenten trockenen Klimas sehr lange erhalten, und (2) dass die Neigung zur Ausbildung von Rumpfflächen, auch in den bald wieder unterbrochenen Zyklen, im trockenen Klima grösser ist als im feuchten. In diesem Formenkreise

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



sind die Merkmale des andinen Gürtels, namentlich die Kare, an den Stellen, wo Firn und Gletscher nur vorübergehend vorhanden waren oder nicht die Oberherrschaft hatten, so deutlich ein aufgeprägtes, gleichsam fremdes Element, dass es oft leicht ist, die Formen verschiedenen Ursprunges zu trennen. Hier ist es möglich, genau zu unterscheiden, was durch die fluviatile Erosion entstanden ist und was man der Erosionsarbeit der Gletscher zuschreiben muss.

Es scheint mir am besten, unter den vielen Beobachtungen, die dazu dienen können, die Frage nach der morphologischen Wirkung der quartären Klimaschwankungen zu beantworten, für den augenblicklichen Zweck zwei Gruppen herauszugreifen, nämlich: eine Anzahl von Beobachtungen über Erosionsniveaus in den Tälern und den Anteil der glazialen Erosion an ihrer Entstehung, und einige Beobachtungen über die wiederholte Anhäufung mächtiger Schuttmassen unter der Einwirkung der Klimaschwankungen, aber in den Talfurchen von Gebirgsteilen, die niemals vergletschert waren.

IV.

Ehe wir aber die Felsterrassen der Andentäler und ihre Beziehungen zu den quartären Gletschern und den Klimaschwankungen überhaupt betrachten, wollen wir uns kurz der hauptsächlichen Ansichten erinnern, die über die Entstehung alter Erosionsniveaus in den Alpentälern ausgesprochen worden sind.

Nach der Ansicht vieler schweizerischer Geologen sind die alten, zum Teil hochgelegenen Erosionsterrassen seit Rütimeyers klassischer Abhandlung über Talbildung in der Hauptsache die Reste alter Talböden der fluviatilen Erosion, von denen die höheren gegen den Gebirgsrand frei ausstreichen.

Eine ganz andere Ansicht hat Hess vertreten. Er meint, man könne an den Gehängen vieler Alpentäler drei oder vier Gefällsknicke erkennen und so ein System ineinandergeschachtelter Tröge unterscheiden, von denen ein jeder durch eine der Vergletscherungen entstanden sei. Noch weiter ist Lucerna gegangen, indem er annahm, dass diese Tröge, wenigstens in den inneren Teilen des Gebirges, hauptsächlich durch die Gletscher der letzten Vereisung und die der späteren Stadien entstanden seien.

Eine vermittelnde Stellung nehmen Penck und Brückner ein. Nach ihren jahrelangen vergleichenden Untersuchungen muss man in den Alpentälern zwei Teile verschiedenen Ursprungs unterscheiden, nämlich: ein System von präglazialen breiten Talböden und, eingeschnitten in den untersten dieser Böden und ungefähr dem Stromstrich folgend, die schmäleren und tieferen Furchen der glazialen Erosion. Dies ist der glaziale Trog, auf den Richter zuerst aufmerksam gemacht hat. Aber der scharfe Gefällsknick seiner Schulter bezeichnet nicht die Lage des alten Gletscherrandes, sondern das Eis hat höher gereicht und noch einen grossen Teil der präglazialen Felsterrassen verhüllt. Die obere Grenze seiner Moränen setzt in dem Wurzelgebiet der Gletscher oft an die sogenannte Schliffkehle an und verläuft hoch oben an dem Gehänge der Täler. Von dem Raume dieser Täler sind im allgemeinen $\frac{3}{4}$ durch die fluviale und $\frac{1}{4}$ durch die glaziale Erosion entstanden. Dieser Teil ist gegen die präglaziale Furche im Mittel um 500 m übertieft worden, das heisst, die kleineren Nebentäler endigen in der Regel in Stufen gegen die Furche der glazialen Erosion.

Wenn wir noch hinzufügen, dass nach GARWOODS und KILIANS Erklärung die Gefällsknicke der Alpentäler vor allem in den Interglazialzeiten durch die fluviatile Erosion nach wiederholten Verlagerungen des Denudationsniveaus entstanden sind, so haben wir einen Überblick der hauptsächlichen Ansichten.

Die grosse Übereinstimmung der grundliegenden morphologischen Elemente des Trockengebietes in den Anden, nämlich aller jener Formen, die nach wiederholten Krustenbewegungen nur durch die fluviatile Erosion entstanden sind, wird noch bemerkenswerter, wenn wir sehen, dass sie sich nicht nur in den drei hier unterschiedenen Gebieten und in sehr verschiedenen Höhen finden, sondern sich auch über Teile von ganz verschiedener Zusammensetzung und Struktur ausbreiten. Die Quer- und Durchbruchstäler des pampinen Gebietes, die, wie zum Beispiel die prachtvollen breiten Felsterrassen der Quebrada de Sanogasta, westlich von der Stadt La Rioja, in steil stehende injezierte Schiefer eingeschnitten sind, haben ihr vollkommenes Gegenstück in den alten Talböden einiger Quertäler, die zwischen dem Rio Diamante und dem Rio Grande im andinen Gürtel in gefalteten mesozoischen Sedimenten liegen und von Basaltströmen bedeckt werden. Für das Punagebiet kann ich ein besonders schönes Beispiel anführen. Es ist der obere Teil des Valle del Cura in der Hauptkordillere der Provinz San Juan. Hier sind zwischen dem Talboden in 3800 m und der Rumpffläche auf der Sierra de Colanguil, in 5000 m Höhe, 16 oder 17 Erosionsterrassen in stark gestörte Granwacken, Porphyrite und Porphyre eingeschnitten.

Es wiederholt sich fast überall dasselbe Bild. Unter einer hoch gelegenen, freien Rumpffläche folgen Talböden aus unterbrochenen Zyklen, die, zum Beispiel, in der Quebrada de Sanogasta noch 600–800 m breit sind. Die Terrassen streichen am Rande der Gebirgszüge in die Luft aus, und man erkennt die Einwirkung der Bewegungen auch an den Störungen der Schotter vor den Mündungen der Täler oder an Verbiegungen der Lavaströme, die manchmal die alten Erosionsniveaus bedecken. Oft kann man auch noch sehen, dass sich die Erosionsterrassen von Quertälern die nebeneinander in einen stetig steigenden Gebirgsblock eingeschnitten sind, bis auf das äussere Gehänge fortsetzen und hier zusammenhängen.

Einen solchen Fall finden wir, im andinen Gürtel in den Quertälern, die in der östlichen Abdachung der Hauptkordillere zwischen dem Rio de Mendoza und dem Rio de los Patos unmittelbar nördlich von der Transandinobahn liegen, in gestörten Quarzporphyren und in deren Tuffen.

Im südlichsten Teile der Abdachung ist die tiefe Furche des Rio de Mendoza, der auch das Schmelzwasser der Aconcagua-Gletscher aufnimmt, in eine alte, ausgedehnte Rumpffläche eingeschnitten, die zwischen 3000 und 5000 m Höhe allmählich nach Nordwesten ansteigt. Reste dieser oder einer etwas älteren Rumpffläche treffen wir auch in der Mitte der Abdachung in rund 5000 m Höhe. Die jüngeren Talböden in tieferer Lage setzen sich so deutlich auf die Aussenseite der Abdachung und in den Zweigtälern von einer Furche in die andere fort, dass über den Tatbestand kein Zweifel bleibt. Zwischen 4000 und 5000 m Höhe finden sich noch einige kleinere Gletscher und in etwas tiefer auch vereinzelte grosse, alte Kare.

In den Quertälern, namentlich im Valle de los Tambillos und seinen Nebentälern und in der Furche des Arroyo del Chiquero, finden sich die Spuren von drei verschiedenen Vergletscherungen. Die Gletscher aller drei Vereisungen sind zum Teil mehr als 20 km lang gewesen. Ihre Seitenmoränen sind meist gut erhalten und lassen oft noch die Wallform erkennen. Die äussersten glazialen Ablagerungen liegen beinahe an dem Fusse des Gebirges allerdings in Höhen über 2500 m. Hier, im andinen Gürtel und hinab bis in das pampine Gebiet, ist eine ausgezeichnete Gelegenheit, die Beziehungen zwischen den Erosionsterrassen und den alten Gletschern zu verfolgen.

Die Form der Talquerschnitte ist hier dieselbe wie im pampinen Gürtel und im Punagebiete. Die oberen Terrassen gehören zu sehr breiten Böden. Der Gefällsknick ist in der Regel da, wo die Terrassenschulter am Gehänge ansetzt, ziemlich scharf. Es gibt auch Querschnitte mit gerundeterer Kurve, so wie wir sie an vielen Stellen in den Alpen sehen, besonders dort, wo sich die Terrassenreste auf einem vorspringenden Gehängesporn finden. Die Neigung der Erosionsterrassen ist viel geringer als die des heutigen Talbodens, der allerdings an vielen Stellen von den Moränen bedeckt ist. Verfolgt man aber die Terrassen von den äusseren Teilen der Abdachung, wo sie in Gehängestufen oder Rumpfflächen übergehen, in die Talfurchen, so sieht man in manchen Fällen, dass sie den heutigen Talboden queren, hier eine Stufe bilden und am gegenüberliegenden Gehänge fortsetzen. Diese Stufen sind in der Regel am höchsten bei den obersten Terrassen, die auch meist am breitesten sind. Zuweilen ist die Stufe zerschnitten und nur noch als Riegel erhalten. Ein sehr gutes Beispiel hierfür findet sich im Tale des Arroyo del Norte.

Es finden sich auch Hängetäler, die aber nicht auf das andine Gebiet beschränkt sind, sondern auch im pampinen Gebiet und im Punagürtel vorkommen, oft mit einer grossen Stufe. Die Beispiele, die ich hier für das einst vergletscherte Gebiete anführen will, treffen wir in der Hauptfurche des Valle de Tambillos auf dessen linker Seite in dem Gürtel zwischen 3100 und 3800 m. Sie liegen unter der alten Schneegrenze. Sie haben nie Gletscher enthalten. Es sind Nischen mit winkligem Querschnitt. Sie werden auf den Seiten von alten Terrassenresten begrenzt und schneiden im Hintergrund an dem noch erhaltenen Stück einer alten Rumpffläche ab. Sie liegen in der Schuttzone und haben kein fliessendes Wasser. Es finden sich acht solcher Nischen nebeneinander und ihre Mündungen liegen 40 bis 80 m über heutigen Talboden, ein wenig über oder unter dem oberen Rand eines steilen felsigen Gehängebandes, das zwei Terrassen trennt. Der untere Teil dieses Bandes ist durch die Seitenmoränen der letzten Vergletscherung verhüllt. Diese Moränen und der heutige Talboden sind viel stärker geneigt als die Verbindungslinie der Mündungen, die mehr oder weniger die Neigung der Terrassen hat. Hier sind die Mündungen ganz deutlich an eines der alten Erosionsniveaus gebunden.

Dass in der Tat die alten Gletscher ein viel stärkeres Gefälle hatten als die Erosionsterrassen, sieht man besonders gut in dem nächsten Quertal weiter nördlich, in der Furche des Arroyo del Chiquero. Hier sind in dem oberen Teile der linken Talseite zwei Niveaus sehr deutlich. Sie liegen in dem Höhengürtel zwischen 3500 und 4300 m. In dem unteren Abschnitt des Haupttales und des von Norden einmündenden Arroyo del Norte kommen hierzu noch vier oder fünf andere Terrassen. Über diese Niveaus ziehen nun die Moränen der zwei letzten Vereisungen, von der Höhe des alten Firngebietes über 4000 m tief bis in das Haupttal hinab. Die Wallform ist oft auf grösseren Strecken ganz scharf, und man erkennt daran, dass die Neigung der alten Gletscher dem Gefälle des heutigen Talbodens entsprochen hat oder sogar noch grösser war. Dies ist dort besonders klar, wo eine Terrassenkante, aus der Moräne heraustretend, mit geringerem Gefälle spitzwinkelig zur Neigung des Walles verläuft.

Aus diesen Beobachtungen ergibt sich, *dass die Felsterrassen bis zu den tiefsten Stufen präglazial sind, und dass in diesen Fällen, bei rund 20 km langen Gletschern, die Erosionsleistung des Eises, wenn sie überhaupt in Frage kommt, nur ganz gering sein kann. In diesem Gebiete haben wir keine Übertiefung durch die glaziale Erosion, wohl aber alle die Merkmale, die man in den Alpen, wo sie freilich zum Teil ausgeprägter sind, als Kennzeichen der Übertiefung betrachtet.*

Man kann hier fragen, ob es sicher s[illegible] ass die Moränen, die wir in so guter Erhaltung finden, wirklich den grossen Vereisungen und nicht den Rückzugsstadien entsprechen. Die Ablagerungen der ältesten von den drei beobachteten Gletschervorstössen habe ich nur an einer Stelle in einem kleinen Vorkommen gefunden. Hinter den Ablagerungen der beiden anderen Vereisungen finden sich in dem mittleren und oberen Abschnitt der Täler zuweilen drei Endmoränen. Dies werden die Marken der Stadien sein. Die Schotterfelder des Alpenvorlandes, von denen wir hauptsächlich auf die Interglazialzeiten schliessen, fehlen in dem Trockengebiet der Anden, oder besser gesagt, die fluvioglazialen Schotter sind mit so grossen Mengen von Schutt vermischt, dass dies Mittel hier versagt.

Der Hauptgrund, dass die Moränen den Hauptvergletscherungen entsprechen, ergibt sich aus der Korrelation der Verhältnisse. Die Kare am Rande des Punagebietes sind, mit ihren kleinen Moränenwällen und ihrem freien Vorland, das erste Glied in einer Kette, an deren äusserstem Ende die grossen Talgletscher stehen. Hierzu kommt, dass sich die untere Grenze des Moränenvorkommen unter sonst gleichen Verhältnissen mit der Schneegrenze allmählich nach Süden senkt. An manchen Stellen kann man auf dieser Linie in aller Deutlichkeit die Grössenordnung der alten Talgletscher erkennen.

V.

Es wäre ein Fehler, von diesen Betrachtungen sogleich auf die Verhältnisse in den grossen Alpentälern zu schliessen, deren aufgestaute Eisströme viel länger und viel dicker waren als die alten Gletscher in dem Trockengebiet der Anden. *Hier haben wir besondere Bedingungen, die man für sich untersuchen muss. Es ist vor allem ein Umstand zu berücksichtigen, nämlich die sehr grosse Breite der Schuttzone und die ausserordentliche Menge von Schutt, die bei der Senkung der Schneegrenze, vom Schmelzwasser durchtränkt, in die Täler geführt worden ist.*

Hierfür finden wir viele Beispiele auch in den Gebieten die nicht vergletschert waren, in besonderer Entwickelung aber dort, wo, im pampinen Gürtel, auch der Einfluss der Sommerregen in Betracht kommt.

Namentlich die Quertäler der Randketten am Gran Chaco, auf beiden Seiten des Wendekreises, sind im Mittel mehrere hundert Meter hoch mit Schutt erfüllt. Hier treten die besonderen Verhältnisse des Trockengebietes, in Beziehung auf die Einwirkung der Klimaschwankungen, scharf hervor. In diesem Gebiete finden sich dieselben allgemeinen morphologischen Verhältnisse wie in den anderen Teilen der Trockenzone. Bowman hat sie aus den angrenzenden Gebirgszügen Boliviens beschrieben. In der Höhe des Gebirges, über 3000 m, sehen wir alte, reife Formen und darunter enge, tiefe und unausgeglichene Furchen. Die Reste alter Erosionsniveaus begleiten aber auch hier die Talgehänge.

Diese Randketten waren nicht vergletschert, obgleich sie zum Teil 5000 m hoch sind. Es fehlen die Kare und die glazialen Anhäufungen. Die Schuttzone ist hier 1000 bis 1500 m breit. Während der Klimaschwankungen ist ihr oberer Teil in den Bereich der Schneeregion gekommen, und ihre untere Grenze hat sich mit der Schneelinie gesenkt. Schon in diesen Zeitabschnitten ist ein grosser Teil des Schuttes, wie im andinen Gürtel, in die Talfurchen geschafft worden. Dies ist noch mehr der Fall gewesen als sich in den Interglazialzeiten die Schneegrenze hob und die schweren Gewittergüsse der Sommerregen bis in den Schuttstreifen hinaufgriffen, der jedesmal aufs neue in den Zeitabschnitten der Klimaschwankungen durch die Senkung der sommerlichen Schneegrenze der Schuttzone angegliedert worden war. Man sieht noch heute grossartige Beispiele von Talverbauung in diesen Gebirgsteilen, wenn unter der Einwirkung der Sommerregen der Schutt in den Tälern durchtränkt und umgelagert wird. Die Talverbauung hat aber in den Interglazialzeiten, als der frische Schutt in grosser Menge aus der Höhe zufloss, ein noch viel grösseres Mass erreicht. Die Schuttströme aus den Nebentälern haben die Hauptfurche abgesperrt. Man kann sehr gut sehen, dass diese Schuttmassen, die an einigen Stellen 800 m mächtig werden, sich an den Seiten und in der Mitte der Talfurchen mit einander vereinigt haben.[1]

Nach einer jeden Periode der Talverbauung und der Schuttstauung hat

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[1] Diese Verhältnisse habe ich kurz besprochen in dem 18. Heft der geologischen Charakterbilder, herausgegeben von H. Stille.

die Erosion tiefe Furchen in die Aufschüttungen geschnitten, und ein jeder Zeitabschnitt der Auffüllung ist durch eine deutliche Akkumulationsterrasse bezeichnet. Hier haben wir eine gute Gelegenheit, auf einem anderen Wege als bei den Schotterfeldern des Alpenvorlandes die Wiederholung der Klimaschwankungen zu erkennen.

Bowman[1] hat schon die Hängetäler erwähnt, die sich unter ganz ähnlichen Verhältnissen in dem benachbarten Gebiete der bolivianischen Anden finden. Auch in unserem Gebiete, in den Quertälern des Rio Bermejo, sind sie häufig. Es sind reife Nebentäler in den hochgelegenen alten Teilen des Gebirges. Gewöhnlich haben sie keinen permanenten Wasserlauf. Sie sind bei der Vertiefung der Hauptfurchen in der Folge der starken präquartären Verlagerungen der Denudationsniveaus mit ihrer Erosionsleistung nicht nachgekommen.

Sucht man die Stellen auf, wo das feste Gestein der Gehänge und des Talbodens unmittelbar unter den ältesten Aufschüttungen hervortritt, so sieht man dass die Hauptfurchen, so wie sie heute beschaffen sind, nämlich mit ihren Erosionsterrassen, ihren Hängetälern und dem ausgeprägten Stufenbau des Talbodens, in der Hauptsache schon vor den Klimaschwankungen vorhanden waren. Wir kommen hier also zu demselben Ergebnis wie bei den Tälern des Punagebietes und des einst vergletschert gewesenen andinen Gürtels. Aber die Untersuchung der Vorgänge bei der Talauffüllung und die Vergleichung der Einzelformen in den drei verschiedenen morphologischen Gebieten lassen erkennen, dass die Veränderungen der Gebirgsoberfläche des Trockengebietes durch den Einbruch der Klimaschwankungen wirklich durch Besonderheiten ausgezeichnet worden sind.

VI.

Sehr auffällig ist der beträchtliche Unterschied in der Masse und der Lage der Seitenmoränen der letzten zwei Vereisungen bei ungefähr gleicher Länge der entsprechenden Gletscher. Er hat bis zu einem gewissen Grade ein Gegenstück in den Unterschieden der Schuttanfüllung und der Einschachtelung der Akkumulationsterrassen in den Tälern der Randketten am Gran Chaco. Dieser Unterschied erklärt sich durch die Abnahme der Schuttzufuhr im Laufe der Klimaschwankungen. Bei der ersten Senkung der Klimagürtel muss die Menge des Schuttes, der in die Täler geführt worden ist, auch im andinen Gebiet sehr gross gewesen sein, besonders dicht unter der alten Schneegrenze, also gerade auf den Talstrecken, die der entstehende oder rasch wachsende Gletscher dann zuerst durchströmt hat. Das erklärt zu einem Teile die sehr geringe oder fehlende Erosionsarbeit des Eises. Eine gewisse Einwirkung des Gletschers auf sein Bett ist auch im Trockengebiet nicht zu leugnen. Man findet Rundhöcker, Schliffspuren an den Talgehängen und ein gewisses Mass von Abschleifung, besonders dort, wo der Gletscher um Talecken geflossen ist. Aber das Gesamtergebnis der Untersuchung ist doch so sehr verschieden von dem in den Alpen, dass

[1] a. a. O.

man entweder im Trockengebiet einen besonderen Fall annehmen oder schliessen muss, das die Erosionsarbeit des Gletschers, namentlich die Übertiefung, sehr gering sei. Ich möchte nicht voreilig sein und will ausdrücklich bemerken, dass ich meine Folgerungen vorläufig nicht auf die Gebirge der feuchten Klimaprovinz ausdehne.[1]

Als allgemeines Ergebnis scheint mir aber wichtig, *dass die Täler in dem trockenen Teile der argentinischen Anden präglazial sind. Die Mitwirkung der Klimaschwankungen bei der Gestaltung der Oberfläche des Gebirges beschränkt sich im wesentlichen auf die Auffüllung der präglazialen Täler mit Moränen oder mit fluviatilem Schutt.*

Die Kare sind zweifellos die prominenteste Form im andinen Gürtel. Aber sie sind Formen der nivalen Klimaprovinz, enstanden in der Hauptsache durch Wandverwitterung und durch Unterschneidung des Gehänges im Bereiche des Bergschrundes. Da die Täler, in deren Einzugsgebiet sie liegen, oder die Abdachungen, die sie krönen, präglazial sind, so gilt dies auch von der Höhe des Gebirges, die wir heute sehen. Die Kare werden also zu einem grossen Teile schon vor den Klimaschwankungen entstanden sein. Die Anschauungen, zu denen namentlich amerikanische Forscher in der deduktiven Entwickelung dieser Formen zu einem nivalen Erosionszyklus gekommen sind, werden sich wahrscheinlich als fruchtbringend erweisen. Die argentinischen Anden mit ihren grossen Rumpfflächen und der Folge ihrer gut erhaltenen Felsterrassen unmittelbar darunter, lassen aber unzweifelhaft erkennen, dass ein solcher Zyklus hier nirgends bis zu einem bemerkenswerten Grade vorgeschritten ist.

Wenn auch die Verhältnisse in dem Trockengebiete der Anden sehr von denen in den Alpen abweichen, so scheinen mir einige vergleichende Betrachtungen dennoch nützlich. Die Erosionsterrassen finden sich nach Süden bis in das feuchte Klimagebiet von Neuquen. Auf der waldbedeckten Abdachung des Gebirges streichen, wie ich selbst gesehen habe, in den Quertälern in der Umgebung des Nevado de Chillan auch die untersten Niveaus frei gegen das grosse Längstal aus. Hier treffen wir heute Bergflüsse, und die 60–80 km. langen quartären Gletscher haben ihre Endmoränen bis in das Längstal vorgeschoben. Da die Menge des Schuttes hier unzweifelhaft viel kleiner gewesen ist als im Trockengebiet, so könnte man schon sicherer auf ein sehr geringes Mass der glazialen Erosion schliessen. Doch ist das Eis auch in diesen Tälern nicht oder nur sehr wenig gestaut worden. In den Alpen sprechen verschiedene Erscheinungen für ein grösseres Mass. Es gehören dazu die Zungenbecken, die Randseen, die Konfluenzstufen und andere. Es ist jedoch beachtenswert, dass auch an diesen eingehend untersuchten Verhältnissen noch so manches dunkel ist. Namentlich die Schärfe der Trogschulter und die Trogschlüsse und die unter der Trogschulter liegenden Terassenreste bieten der Erklärung Schwierigkeiten. Man

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[1] Inzwischen habe ich mich durch eine Begehung des Reus- und des Tessintales im Oktober des vorigen, und beim Abschluss meiner geomorphologischen Untersuchungen in der Hauptkordillere, im Januar und Februar dieses Jahres, überzeugt, dass man sie, mit unwesentlichen Einschränkungen, auf diesen Teil der Alpen ausdehnen kann.

mag schliesslich hierüber denken, wie man will: *die eindeutigen Erscheinungen in dem Trockengebiet der Anden, wo sich die Täler über grosse Strecken und unter verschiedenen geologischen Bedingungen bis zu den Einzelformen als präglazial erweisen, können bei neuen Untersuchungen der komplexeren Gebiete als Anhalt dienen.*

DISCUSSION SUR L'EROSION DANS LES CORDILLÈRES ARGENTINES.

P. QUENSEL (Upsala): Mr. WILLIS mentioned the trans-Andine valleys as beautiful examples of backward erosion of the Pacific rivers. The greater fall and the very much more humid climate of the western slopes of the Cordillera would, without doubt, be much in favour of a hasty backward erosion, but it must not be forgotten that the Ice Age has, more than anything else, been responsible for the formation of the water-shed of the present day. How much backward erosion was performed by the Pacific drainage in pre-Glacial time can hardly as yet be estimated. In post-Glacial time, however, backward erosion seems to have played a very insignificant part. During nearly two years of geological work in South Patagonia I had some opportunity to study the glacial geology of that region[1] and am of the opinion regarding the post-Glacial evolution of the Patagonian drainage that the iceshed, during the Glacial period, corresponded closely to the central zone of the Cordillera, and that in late Glacial time the drainage of the eastern Cordillera followed the pre-Glacial valleys eastward to the Atlantic.

As the ice drew back great amounts of glacial detritus were deposited in these valleys. The erosive power of the ice was limited. On the eastern slopes of the mountains the great sub-Andine lakes were excavated. Morphologically these lake basins belong to the pre-Glacial valleys of the Atlantic drainage (in their western parts deepened by glacial erosion, in their eastern parts filled up by detritus of the receding ice), and while they were dammed by glacial deposits on the east the ice still barred any possible outlet toward the west.

As the last ice disappeared from the Cordillera some passes were opened to the Pacific and the drainage was suddenly reversed. Fine terraces mark the levels of these ice-dammed lakes. In some cases the pass to the west was low enough to drain the whole lake. How much of the excavation of these trans-Andine passes was done by backward erosion in pre-Glacial time, or how much they were lowered by glacial erosion, is difficult to estimate. Without doubt, both forces have coöperated.

The watershed of the present day in the broad pre-Glacial valleys, generally consisting of glacial deposits, has not been formed, however, by the slow backward erosion of the Pacific rivers, but by the rivers that existed during the last disappearance of the Andine ice-sheet, whereby lower passes have been opened to the west.

The different terraces of the old lake basins, without doubt, mark passes of different height that were successively found through the mountains and can hardly be explained by a reversal of drainage through backward erosion.

G. STEINMANN (Bonn) bemerkt, dass begreiflicherweise in Südamerika derselbe Gegensatz in den Ansichten über die Bedeutung der Glazialerosion hervortritt wie in Europa und in Nordamerika. Er betrachtete durch die Beobachtungen des Herrn KEIDEL als erwiesen, dass in Trockengebieten die Glazialerosion eine Abschwächung erfahren kann; er möchte aber andererseits betonen, dass er in den Kordilleren von Bolivia und Peru dieselben auffallenden Wirkungen der Glazialerosion beobachtet hat, wie in den Alpen, d. h. die Übertiefung der Täler, die echten Hängetäler, die ausgeschliffenen Felsbecken u.s.w. Auch betrachtet er die Darbietungen der Wasserscheide in der patagonischen

[1] *Influence of the ice age on the continental watershed of Patagonia;* Bulletin of the Geological Inst. of Upsala, Vol. IX (1910).

Kordillere als eine glaziale Erscheinung, wie die ähnlichen Vorkommnisse in den Alpen (Maloja) oder in den europäischen Mittelgebirgen (Höllental im Schwarzwald).

Um eine sichere Grundlage für die Beurteilung der Glazialerosion zu gewinnen, muss man die statistische Methode anwenden, d.h. man muss feststellen, durch welche Merkmale früher sicher vergletscherte Gebiete ausgezeichnet sind vor den nicht vergletschert gewesenen. Was sich überall in den Gebieten früheren Vereisungen wiederholt und anderorts fehlt, ist das Erzeugnis der Eiswirkung.

J. W. EVANS (London) referred to a paper read by him some years ago before the Royal Geographical Society and published in the Geographical Journal, in which he showed that the position of the watershed of the Andean region depended on the direction of the prevalent wind that brought the rainfall. In these latitudes, where the southeast trades prevailed, the eastward flowing rivers traversed range after range in deep gorges, some at only a very moderate elevation above the sea; while farther south, where the northwest winds blew, the conditions were reversed. He was inclined to consider these relations as due not so much to the retrogression or working back of the river valleys as to the fact that rivers flowing towards the side on which the rainfall was deficient were liable to be diverted by earth movements, while those where rainfall was abundant were able to maintain their courses.

It was not necessary, therefore, to attribute the position of the watershed in Patagonia to the glaciation to which that region had been subjected, though this had no doubt affected important changes in the form of the surface.

H. KEIDEL (Buenos Aires): Die Durchbruchstäler der patagonischen Kordillere sind gewiss Furchen von sehr verwickelter Entstehung. Ich glaube aber nicht, dass hierbei die quartären Gletscher den Anteil gehabt haben, den ihnen Herr QUENSEL zuschreibt. Ich stimme Herrn BAILEY WILLIS und Herrn EVANS bei, wenn sie sagen, dass andere Umstände eine grössere Bedeutung haben. Gerade die patagonische Kordillere ist eine ausgeprägte Klimascheide und dabei ein sehr regenreiches Gebiet. Auf der pazifischen Seite haben wir die Winterregen und die beständigen Westwinde, und es gibt manche Anzeichen, dass diese Verhältnisse seit langem bestehen. Auf der atlantischen Seite beginnt aber, schon am Fusse des Gebirges, die Herrschaft des halbtrockenen Klimas in dem Gebiete der Mesetas. Es haben deshalb bei der Durchschneidung des Gebirgswalles alle die Umstände zusammengewirkt, die hier erwähnt geworden sind; indem sie vom pazifischen Ozean her die rückgreifende Erosion sehr verstärkt haben. Es sind die grössere Steilheit dieser Abdachung und der kürzere Weg zur See, die Herr BAILEY WILLIS hervorhebt, die Beständigkeit der Winde von einer Seite her, auf die Herr EVANS für die Bildung bolivianischer Täler Gewicht legt, und vor allem, wie ich meine, die ungleichmässige Verteilung der Niederschläge. Sicher hat, wo es so grosse Eisströme gab und eine so mächtige Inlandeisdecke vorhanden war, auch die glaziale Erosion mitgewirkt. Aber, ich will es wiederholen, die Erscheinung dieser Durchbruchstäler ist complex, wie weiter im Norden, im Trockengebiete, wo wir ausserdem noch, an morphologischen Merkmalen, den Einfluss von Bewegungen sehen und die Mitwirkung der Verdämmung durch Lavaströme und ihre Tuffe und durch Schutt.

W. PAULCKE (Karlsruhe): Bei der Frage nach der Entstehung der grossen Durchbruchstäler lauteten die Antworten fluviatile Erosion *oder* Glazialbildung. Das Rückwärtsverlegen der Wasserscheide, das Abzapfen benachbarter Einzugsgebiete wurden dem einen *oder* dem anderen Agenz zugeschrieben. Mir scheinen solche Erscheinungen in den meisten Fällen *complexer Natur* zu sein. Ich bin überzeugt, dass mächtige Gletscher intensiv erodieren können, aber ebenso sicher scheint es mir zu sein, dass das erste Ausarbeiten von Durchbruchstälern der Erosion des fliessenden Wassers zuzuschreiben ist, welches den durch die gegebenen Neigungsverhältnisse vorgezeichneten Weg nahm.

Als durch tektonische Vorgänge (Hebung oder Senkung) grosse Niveaudifferenzen geschaffen wurden, musste sofort Wassererosion, und zwar am schärfsten auf den Steilseiten (Anden-Westen, Alpen-Süden, Schwarzwald-Osten), einsetzen, und musste sich intensiv rückwärts in den Gebirgskörper einarbeiten. Schon vom Anfang an begann die Kampf um die Wasserscheide wobei (ceteris paribus) die Wasserläufe auf der Steilseite das Einzugsgebiet der weniger geneigten Flanken abzapften.

In der darauffolgenden Zeit intensiver Vereisung modifizierten du. a die Gletscher die von ihnen vorgefundenen Talrinnen, übertieften sie intensiv, schufen die typischen Glazialtäler, bis dann, nach Verschwinden des Eises, wieder Wassererosion kräftig einsetzte und nun auch alte Glazialtäler, wie das Inntal bei Maloja, das Obere Höllental im Schwarzwald etc., abzapfte, und so alte Glazialgebiete in ihren Machtbereich einbezog, wie z. B. bei Maloja und im Höllental.

Die Reihenfolge in den in Rede stehenden Fällen muss stets gewesen sein: erst Gebirgsbildung, dann Wassererosion, dann Eiserosion, schliesslich abermals Wassererosion, die jetzt am Werke ist.

BAILEY WILLIS (Washington): In regard to the comment of Dr. QUENSEL that certain river courses in the Andes have been reversed by glacial interference and transferred to the Pacific, our observations confirm his. The Rio Epuyen in latitude 42° is thus transferred. The glacier spread eastward, descended through a wind-gap to the Pampas, dammed a valley by a moraine, produced a lake and maintained the lake so long that the outlet-stream cut a canyon across a ridge to Pacific waters. These facts are plain, and in regard to such cases there can be no difference of opinion. Those which I have observed occur in the eastern range of the Cordillera. It is otherwise with the canyons that traverse the western range in these latitudes. They are long, deep, well developed river canyons, comparable in character and dimension with the pre-Glacial canyons which the glaciers in the Andes deepened to form rock-bound lake basins. They descend the western slope of the range to the nearby and low-lying lakes or sounds in Chile. They are favourably conditioned for retrogressive stream action, which cut the canyon of Nahuel Huapi, for example, and may reasonably be attributed to the same action at the same epoch. They are not related to glacial dams, glacially confined lakes or outlets of such lakes. Thus they are distinguished by both positive and negative evidence from the glacial transfers, which occurred after retrogressive stream erosion had cut through the western range.

My observations in northern Argentina though far less extensive than the studies by Dr. KEIDEL, agree with his. The peneplains and mature erosion surfaces of the high Andes I take to be pre-Pleistocene. The rock terraces are remnants of valley floors, which have been cut through by successive activities of the streams. Glacial erosion is there a negligible phenomenon as the glaciers were small, were not confined, and spread their tongues upon enormous masses of gravel and detritus. Nevertheless, it will not do to conclude that glaciers do not erode. In the humid region of the Andes, where glaciers attained 1,000 to 1,500 metres in depth, where they descended from high basins into very deep and narrow canyons, the bottom ice was under enormous head and excavated deeply, producing the very deep lake basins of Lago Nahuel Huapi and other similar lakes. The discussion of glacial erosion cannot advance to an intelligent understanding of the process and its results unless we recognize that the glacier is a tool which may erode or may not, according to the conditions of head and confinement, which force it down, or of freedom to spread, which leaves it a superficial covering of the ground.

H. KEIDEL: Ich will hier noch einmal hervorheben, dass ich als das wichtigste Ergebnis meiner Beobachtungen die Tatsache betrachte, dass die Täler des Trockengebietes in den argentinischen Anden so allgemein präglazial sind bis zu den kleinen Terassen und Stufen nahe am Talboden. Auch auf das Alter der patagonischen Täler wirft dies Ergebnis, meine ich, einiges Licht. Die Täler etwas weiter nördlich, in der Umgebung des Nevado de Chillan, die schon im Regen- und Waldgebiet liegen, wo breite Flüsse fliessen und 80 km lange Gletscher vorhanden waren, zeigen im Ganzen, wie ich gesagt habe, dieselben Verhältnisse wie die Täler des Trockengebietes. Wir sehen hier dasselbe freie Ausstreichen der untersten Erosionsterassen gegen das Längstal und die Kreuzung im Gefälle dieser Terassen und der Moränen. Weshalb können also nicht auch die Täler der patagonischen Kordillere präglazial sein, auch wenn die Fortsetzung des chilenischen Längstales im Süden gesenkt worden ist und heute unter dem Meeresspiegel liegt? Dies ist wenigstens sehr wahrscheinlich.

Wenn auch die Frage nach der Grösse der glazialen Erosion in ihrer allgemeinen Fassung durch meine Untersuchungen im Trockengebiet nicht beantwortet wird, so geben sie uns doch die Aussicht manche, noch dunkle Erscheinungen der complexeren Gebiete aufs neue, mit besserem Erfolge, zu untersuchen. Es sind hier die Täler des Schwarzwalds erwähnt worden. Aber gerade manche Täler auf der westlichen Seite, wie z. B. das Kinzig- und Gutachtales und ihre Seitenfurchen, zeigen ähnliche Verhältnisse, wie ich sie beschrieben habe. Wir treffen auch hier grössere Rumpfflächen, die sich vom kristallinischen Gebiet bis in den Buntsandstein der württembergischen Seite erstrecken, wir sehen Erosionsterassen darunter, und schliesslich auch Talriegel, als die Reste solcher Terassen und auch Hängetäler; diese Erscheinungen, sage ich, ähneln denen des Trockengebietes; sie sind als Übergangsgebiet zu den grossen Alpentälern, ein ausgezeichnetes Objekt für die Untersuchung.

Contributions diverses: Tectonique.

THE ANGLE OF SHEAR.

BY

TH. DAHLBLOM,

Superintendent of Mines, Falun, Sweden

The force of gravity creates a stress in the steep wall of a mine or in the side of a mountain, in the direction of least resistance. This action may be conceived as a wedging away of the rock from behind, or the force of gravity may be regarded as divided into two components, one in the direction of the least, the other in the direction of the greatest resistance (Fig. 1).

When the stress exceeds the tensile strength of the rock, a part will be wedged off. And, since the stress increases with the steepness of the exposed slope, the ratio between the stress and the tensile strength will result in a varying slope. The angle which this slope makes with the perpendicular is the angle of shear or the angle of pull.

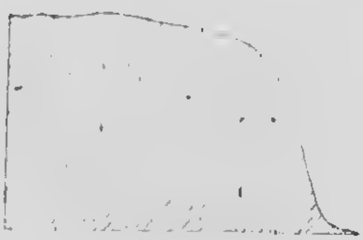

FIG. 1.

FIG. 2.

The angle of shear depends not only on the tensile strength, but also on the elasticity of the rock. There is exerted against the plane A B (Fig. 2), both the pressure due to the weight of the rock above (= p) and the pressure due to the wedging force (= s), the resultant of which is u. This raises the compression of the rock in the section A B above the normal. And this abnormal compression causes a little sinking and also a slight horizontal movement of the rock between C and B, in consequence of which joints are opened and the cohesion or tensile strength of the rock is reduced.

If a large part of the rock falls, the sudden removal of the compressing mass will allow a sudden expansion in the abnormally compressed region, and this release manifests itself locally as an earthquake or concussion, which has the effect of reducing the friction. The initial friction, which is much greater than the friction during motion, is thus reduced and the rock-fall and the angle of shear are correspondingly increased to much greater values than they would have had if the adjustment had been accomplished by creep or wedging off of small masses. Examples of this are afforded by great landslides, as that at Frank, Alberta, in 1903, where the angle of shear amounted to 52°–55° 20′.[1]

Since the weight of the rock causes the stress, and the pressure due to weight increases with depth, the stress and the angle of shear must also increase with the depth. Also, great stress will cause rock-flowage. Hence, at sufficient depth the rock will be nearly plastic and the angle of pull or shear will be nearly 90°, as it is in liquids. Under insignificant pressure, on the contrary, the angle of shear will be negative, resulting in a vaulted room (Glockenbildung), a very common feature in the mining of coal or ore-seams (Fig. 3).

The question is, therefore, very complicated. The angle of shear depends on the pressure, the strength of the rock, the joints or cleavage in it, and on the size of the caved and unstable rock-mass. The angle of shear will be tangent to a curve (A B, Fig. 4).

FIG. 3.

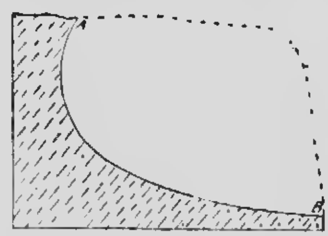

FIG. 4.

The sides and bottoms of deep valleys are generally covered by talus, the weight of which balances the horizontal pressure. In mines worked by caving, the débris also offers more or less resistance to the horizontal force; consequently, reports on areas that have been mined should contain information not only as to the depth to which a mine has been worked out, but also as to the approximate depth of the débris in it. Information regarding this question is desirable, especially for mining men, and the experience accumulated in mining and railway and canal construction is the only source of this information. Collected, it means the conservation of life as well as money.

[1] *The great landslide at Frank, Alberta;* Sessional Paper No. 25, Ann. Rep. Dept. of the Interior, Canada, 1903.

LANDSLIDES AND THE SINKING OF GROUND ABOVE MINES.

BY

ERNEST HOWE,

Newport, R. I., U.S.A.

In many regions the settling of ground above extensive mine workings is of common occurrence and leads to serious damage to property on the surface, not only immediately above the mines, but often at considerable distances away.

The force of gravity, exerted vertically downward, that tends to overcome equilibrium in a partially supported mass of rock or earth may be resolved into two components, one of which is in the direction of least resistance to movement; the angle that this component makes with the vertical has been called the "angle of pull." The surface area subject to disturbance depends upon the various angles of pull of the unstable ground, and a determination of these angles may sometimes be a matter of considerable importance.

Although the problem as suggested by DAHLBLOM is largely an engineering one, it may be considered with advantage from a geological point of view. PENCK has considered theoretically the conditions that may lead to landslides,[1] and has shown that they are dependent on certain factors, some of which are purely mechanical while others are largely geological. These factors are the *weight* of the unstable mass, the *cohesion* of the rock, the *coefficient of friction* for the different materials involved, and, finally the *angle of inclination* from the horizontal of that surface which is one of least cohesion of the rock mass with the parent rock. Of these factors, the cohesion, or strength of the rock, together with the coefficient of friction, are dependent on a number of strictly geological conditions, and it is obvious that they have a direct influence on the value of the angle of pull. It is the purpose of the present paper to call attention to these geological factors; as far as they are concerned, the settling of ground above mines does not differ materially from surface slides, so that a review of the conditions affecting them may be of interest in the present connection.

In a study made some years ago in the mountains of southwest Colorado, the causes that were believed to have been responsible for the numerous landslides were summarized as follows:[2]

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[1] PENCK, A., *Morphologie der Erdoberfläche*, I, 222-231, 1894.
[2] HOWE, E., *Landslides of the San Juan Mountains, Colorado*. Prof. Paper No. 67, U.S. Geol. Surv., Washington, 1909.

Internal Causes:

1. *Physical condition of the rocks.* Cohesion, jointing, presence of soft or incompetent layers.
2. *Structural conditions.* Folding, faulting.
3. *Topographic conditions.* Oversteep hillsides or cliffs.

External Causes:

1. *Earthquakes.*
2. *Readjustment of stresses within the mountains.*
3. *Saturation of the ground by water.*
4. *Frost.*

These causes are essentially the same as those recognized by HEIM and others who have studied landslides in mountain regions.

It is unlikely that any one cause has ever been responsible for a landslide. In all cases that have been studied it has been found that two or more of the conditions mentioned have, in all probability, combined to bring about landslide action. It is agreed by all observers that internal conditions favourable to landslides may continue for long periods without any movement on the part of the threatened mass, and that some external element is necessary to give the final shove, as it were, which sets the unstable material in motion. It is improbable that any one, or even all, of the external causes could initiate landslides in a region of stability or where internal conditions favourable for landslides were lacking. The internal causes may be likened to the charge of dynamite in a drill-hole while the external cause is comparable to the lighting of the fuse.

Probably the commonest of the external causes of landslides is saturation of the ground by water. By this process the weight is increased and the coefficient of friction reduced, while, if the element of cohesion enters into the conditions, it also may be affected by the presence of water. In a large majority of landslides of which there are definite records and the pre-existing conditions are known, long continued or unusually heavy rains occurred before slipping took place.

Leaving the question of variation in weight of the unstable mass to the engineers, it will be seen that, other things being equal, the value of the angle of pull is directly dependent on certain physical and structural conditions of the rocks. As suggested under the head of the internal causes of landslides, the structural conditions of folding or faulting, jointing, and the presence of soft or incompetent layers are undoubtedly the most important from a practical point of view, since cohesion may be reduced to zero by any one of these factors. Nevertheless, weak rocks with little tenacity together with a low coefficient of friction, may offer ideal conditions for landslides, even if the other factors are lacking.

Many of the landslides of greatest magnitude in southern Colorado have been attributed to a shale horizon 375 metres thick which has failed to support massive rocks resting upon it. Sedimentary beds or rocks having a strongly developed slaty cleavage dipping in the direction of pull of an overlying mass present conditions of weakness which, in the case of sedimentaries, may be increased by the presence of a layer of rock more yielding than the rest. In massive rocks fault-planes or joints inclined in the direction of pull present conditions of weakness similar to those of upturned sedimentary rocks. The extensive jointing of the massive volcanic rocks of the San Juan mountains has undoubtedly been responsible for many of the landslides, not only because lines of weakness were thus defined, but also because the jointing permitted the saturation of the relatively impervious rocks by water.

While internal conditions are subject to observation and study, external causes must in large part remain unknown. In other words, it is frequently possible to state with assurance that landslides are likely to occur, yet it is manifestly impossible to predict just when a slide may take place.

Slips from the sides of a railway cut or canal are often comparable to landslides due to natural causes in regions of youthful topography, but they and the sinking of ground above mines may present a number of factors, due to the hand of man, which do not enter into a consideration of landslides proper. Nevertheless, many of the internal causes which have been recognized as responsible for landslides must hold true in the case of mine caves. The slides from both sides of the Culebra cut at Panama illustrate this very well. It was early recognized that the naturally weak shales and sandstones would tend to slip in as excavation increased in depth, although the structural conditions were those of stability. The method of excavation undoubtedly contributed very largely to the cause of the landslides, as it was necessary to loosen the ground by heavy blasting in order that the rocks might be readily handled by steam shovels. As a result of this blasting, the rocks were shattered for some distance back from the face of the cut, developing new planes of weakness, permitting the entrance of surface waters, and further reducing the already low cohesion. The steep natural slopes characteristic of the Isthmian topography can not be taken as criteria for determining the angles of repose for the sides of the canal, because they have been developed by natural processes extending over a long period of time through which the cohesion of the underlying rocks has not been reduced.

Without attempting to give further examples, it must be seen that the conditions favourable to landslides must also apply in large part to the settling or caving of ground above mines. While the angle of pull for landslides is mainly determined by structural and topographic conditions, certain other factors must enter the problem in the case of mines. In any engineering study it will be necessary to recognize that the problem does not have to deal with homgeneous materials but with rocks of varying degrees of hardness or strength, and it may be further modified by faults, joints, bedding planes, and layers of softer rock, while ground-water undoubtedly plays a far more important rôle than in the case of landslides. Careful estimates of pressure and painstaking determinations of the crushing or tensile strength of selected samples of rock are likely to be of little value if the presence of faults or joints is overlooked, while in stratified rocks a single incompetent layer, unnoticed by an engineer, may upset his nicest calculations. Numerous detailed geological sections should be of the greatest value in this connection.

In addition to the natural internal causes several external conditions that may bring about sudden or gradual movement of the ground must be considered; although due to the hand of man, two of these are comparable to some of the natural external causes of landslides. One is the readjustment of stresses in the country rock due to the rapid artificial removal of large volumes of material. Another external cause is the probable cumulative effect of the faint shocks due to blasting. A singlo sheck is not likely to be the direct cause of an extensive cave as earthquakes have been known to touch off landslides, but it is quite probable that shocks repeated day after day may at last overcome cohesion along previously determined planes of weakness. Neither of these factors can be eliminated, and although less patent than some of the others that have been enumerated, their influences must be taken into account in any study of the causes of the sinking of ground above mines and the determination of the angle of pull. The improbability of ever finding exactly the same physical conditions in any two localities must prevent the adoption of any set rules for the determination of the angle of pull, but the sympathetic coöperation of engineers and geologists in the study of this important problem should result in the development of a definite method of investigation sufficiently broad to apply in all cases.

EXCAVATION DEFORMATIONS.

BY

DONALD F. MacDONALD,

Geologist, Isthmian Canal Commission.

Mr. Dahlblom has opened up for consideration a very fertile field. His paper on *The Angle of Pull* is one that merits much attention and discussion. The kind suggestion of Director Brock of the Geological Survey of Canada, has prompted me to offer in this paper certain studies made on the slides of Culebra Cut, and I shall be glad if the ideas advanced will help in any way to stimulate discussion and broaden interest in this important subject.

DEFINITION OF TERMS.

To me, the term "angle of pull" has a clear-cut meaning quite different from that which Mr. Dahlblom has given it. Excavation deformation, I believe, expresses better the phenomenon he so interestingly discusses.

Mr. Dahlblom thus clearly defines the subject of his paper, "The . . . wedging power . . . of gravity . . . tends to wedge off parts of a steep mountain, or steep wall of a mine, until a certain slope is reached. The angle between this slope and the perpendicular is the angle of pull." Now, any excavation in the earth's crust sets up stresses in the contiguous rocks, because of the unbalanced pressures created by the substitution of atmospheric pressure for the greater pressure of the material excavated. These stresses are divisible into two distinct groups: (a) crushing or direct gravity

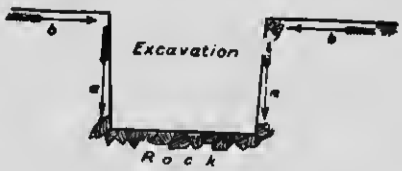

Fig. 1

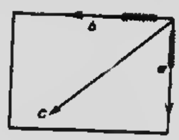

Fig. 2

stresses, which have a maximum effect near the toe of the steep slope of the excavation; and (b) tensional or flowage stresses, also due, though less directly, to gravity, which exert a horizontal pull toward the excavation and give maximum deformation near the surface (see Fig. 1). Now, the resultant (c, Fig. 2) of these two groups of stresses might be referred to as the angle of pull. This resultant, however, would be a most complex thing, because there are not two forces at work, but only two main types of strain or tendencies to deform, one in a vertical, the other in a horizontal direction. These are, of course, split up into lesser strains in various directions, but all are the result of one force, namely, gravity.

In the case of an excavation in solid granite, for instance, the resultant angle of pull might approach 45°, while the angle of the actual slope remained at 90°. How far away from the perpendicular through the intersection of the slope and bottom plane of any excavation may rock movements, due to that excavation, affect structures? What name shall we apply to that zone around any excavation within which a structure may be disturbed by rock movements resulting from that excavation? The following terms suggest themselves:

1. Angle of pull.
2. Angle of no deformation.
3. Angle of permanent slope.
4. Excavation deformation.

In Culebra Cut, deformation movements, well below the actual excavation which produced them, have resulted in a bulging up of the bottom and a cracking of the ground far back from the slope of the Cut. After studying these, the writer believes that the term angle cannot in any sense be used to apply to the measure or to denote the magnitude of such deformations, hence his use of "excavation deformation" as a more suitable name for all phases of the phenomena under discussion.

ANALYSIS OF CONDITIONS.

Two major classes of excavations set up strains in contiguous rocks: those due to processes of nature, as stream erosion, solution, fault escarpments, etc.; and those due to works of man, chiefly open-cuts, underground workings and submarine excavations. The extent to which any excavation will cause deformation of the contiguous rock material depends on the following factors:

1. Crushing strength of large masses of the material involved.
2. Tensile strength of large masses of the material involved.

   Both 1 and 2 vary according to (a) the strength of the small component masses, (b) the character of the jointing, (c) the character of the bedding, and (d) the fault conditions.
3. Physical and chemical character of the rock units.
4. Amount and character of the ground-water.
5. Earth tremors set up by earthquakes, blasts, passage of railroad trains, or due to other causes.
6. Other factors, as (a) heavy structures contiguous to excavations, (b) water freezing in rock openings and wedging off rock masses, (c) variation of barometric pressure, (d) earth strains from the kneading of tidal pull.

1, 2. Crushing and tensile strength of the rocks involved.

If a rock has high crushing strength, with few joint or other planes, it will stand at an almost perpendicular angle, at any height with which we need to have concern. If it has high crushing strength in small solid fragments, but is much cut by joints, faults or bedding planes, it will not deform or flow but will slough off masses from steep slopes, until a certain angle is attained. Under such conditions such an angle might be called the angle of no deformation, because the slope would not further deform. Fissures, faults or bedding planes that incline toward the excavation are very efficient promoters of slides. This is especially true where bedding planes have shale, lignite, or other greasy rock partings, or where the fault planes contain talcose clays. Even in cases where such partings are horizontal, relatively light back pressure may push the material which rests on them out into the excavation.

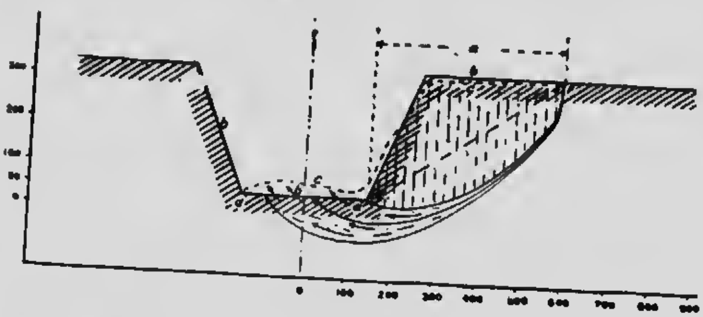

Fig. 3

Ideal cross-section to illustrate excavation deformations. *a* = width of zone deformation, measured from toe of slope; b = original surface; *c* = surface after deformation; *d* = bottom of excavation before deformation caused it to bulge upward; *e* = toe of slope, intersection of slope and bottom planes; *f* = crack, or break, caused by deformation of basal part of the block, which is shown with perpendicular broken lines. The curved lines from *f*, with arrows at the bottom of the excavation, are to show approximately the chief zone of deformation and the direction of the motion.

In cases where the rock has low crushing strength, but relatively high tensile strength, any movement will manifest itself as a deformation or sinking near the excavation, with a slight excavationward advance of the lower slope, and a bulging up of the bottom (see Figs. 3, 8). Some conditions very similar to this have existed in Culebra Cut. In most cases, however, they generally go beyond this stage as the work of deepening the Cut proceeds. If we imagine a plane (*ef*, Fig. 3) to extend through the intersection of the slope and bottom (*e*), and through the point of farthest deformation (*f*), the angle which this plane makes with the perpendicular will not necessarily measure the angle of the actual effective pull of gravity which may be greater than this; neither will it measure the angle of "no deformation," for some deformation of the rocks (Figs. 3, 8) has certainly taken place below this plane. It does not measure the angle of permanent slope, for that may correspond with the dotted line (c). The term "angle," as applied to the measure or extent of excavation deformations, is therefore misleading.

As an alternative the following notation is suggested. Let us say that an excavation 50 metres deep caused a deformation in the contiguous rocks to a distance of 150 metres in a horizontal direction from a vertical line at the toe of the slope (c, Fig. 3). This phenomenon may be referred to as an *excavation deformation of 50 on 150 metres.* This notation indicates not only the depth of the excavation and the width of the zone of deformation but, if plotted, it will also give an angle which in some cases may correspond with the final slope. Engineers now often refer to slopes as being 1 on 1, 1 on 2, etc., meaning 1 unit up and 1 or 2 units over. This, however, is only a measure of the angle of slope unless the actual number of units of depth of excavation and width of deformation zone are given. In cases where the rock has a very low crushing and a very low tensile strength, conditions would, in the absence of excessive mobility due to ground-water or other causes, approach those of an excavation in sand, where the slopes would be permanent when they had reached the "angle of repose" for the material involved.

3. *Physical and chemical character of rock units.*

Very soft rocks, especially very fine-grained and compact argillites and clays, may stand at an almost perpendicular angle until the excavation reaches a depth of 15 to 40 metres, or until the unbalanced pressure is great enough to cause them to deform. This deformation destroys the stability of their clayey cementing material, loosens them up for the invasion of quantities of ground-water, which their fineness of grain excluded previous to deformation, and induces muddiness and mobility, so that the slope may break back from almost perpendicular to 1 on 10. Deformations closely approaching this have occurred in Culebra Cut in some of the volcanic clay rocks.

Excavations which lower the level of the water-table may weaken the surrounding rocks by leaching out and loosening their more soluble parts. This is especially likely to be true in a region of abundant rains and vegetation, where the ground water contains a high content of carbon dioxide and organic acids. On the Canal Zone the limestones contain many caves, small caverns, enlarged joints and pitted surfaces, evidences of comparatively rapid solution. Certain basic volcanic clay rocks of about andesitic composition crumble very rapidly when they are dug out of Culebra Cut and exposed to weathering action. Boulders of this soft rock, two or three feet in diameter, crumble into clay in less than a year. This seems to be due to:

(a) Absorption of rain water and heavy dews by the outer layers of these clay rocks, with succeeding drying out by the hot sun. By this process soluble salts are leached out and are sometimes deposited on the outside of the rock, as barely noticeable white coatings or as scattered, minute, translucent crystals. These seem to be largely magnesium, iron and calcium sulphates. This wetting, drying, and leaching loosens up the small individual grains and they drop off, thus removing layer after layer until the whole rock is disintegrated.

(b) Oxidation, which gives an increase of volume and increases the tendency to disintegrate. These rocks have a considerable percentage of ferrous iron (up to 3.7 per cent.), which is somewhat oxidized to the ferric condition by contact with the atmosphere and oxygen-bearing rain water.

4. Amount and character of ground-water.

Ground-water in rocks is an important weakening factor It augments the tendency toward deformation of rock masses chiefly, (1) by adding weight to a rock mass, which may already be strained toward an excavation, (2) by weakening a rock through solution and softening, and (3) by increasing the mobility of a mass of rock material. In cases where a relatively porous material rests on top of relatively impervious rock, especially if the plane of contact slopes toward an excavation, ground-water or rain will add weight to the porous mass by filling its interstices. It will also soften and weaken the porous material, and greatly decrease its adhesive grip on the sloping surface of the relatively impervious rock. The water will descend through the porous material, but will be deflected by the relatively impervious rock; and on this impervious surface will be deposited the mud particles and other lubricating material gathered in descent. The contact thus becomes a slippery zone which greatly promotes slides. Even capillary water in a weak rock is a source of danger, for with deformation much of the capillary water may be crushed into the larger shear planes, thus giving them increased lubrication. In estimating the sliding or deforming tendencies of a rock careful determinations of its water content should be made on both fresh and atmospherically dried samples. The most troublesome slides of Culebra Cut occur in fine-grained basic volcanic clay shales of fairly massive character. These show 6 to 17 per cent. of water. Two samples analyzed in the U. S. Geological Survey laboratory gave 12.26 and 9.47 per cent. of water when the sample was heated below 100°C, and 5.41 and 6.71 per cent. when heated above 100°C. Many minute particles of chlorite that were present probably added not only to the content of water but also to the greasy and slippery character of the rock.

5. Earth tremors.

Earth tremors are a cause of deforming movements in rock masses. Earthquakes are the most powerful of these. To blasting, however, may be attributed the earth waves that shake down most material into excavations where it is not wanted. A blast generates two sets of vibrations, one transmitted through the earth, the other through the atmosphere. The atmospheric vibrations travel apparently with the same velocity as sound, the earth vibrations much faster. Surface blasts expend a greater proportion of their energy in atmospheric vibrations than do deep blasts. Hence, surface blasts make much more noise and jar houses more than deep blasts, but they affect slides very little. On the other hand, the tremors created by deep blasts help to bring down, even at considerable distance from the explosion, rock masses already dangerously strained. Two large blasts in Culebra Cut gave the following approximate vibration records. A blast of 2,250 pounds of dynamite, exploded in 14, 24 and 28-foot holes, gave a maximum amplitude of 20 mm. at 1,100 feet from the instrument. Another blast of 5,370 pounds of dynamite, exploded in forty-eight 24-foot holes at about the same distance from the instrument, gave an amplitude of 28 mm. These records were made on an imperfect instrument rigged up temporarily by Mr. C. M. Saville, one of the engineers. Its magnification was about 10, so that the amplitudes of the earth waves set up by the blasts were about 2 and 2.8 mm. respectively—quite enough to damage seriously a steep slope of brittle rocks already heavily strained. Vibrations from railway trains may also damage slopes that are already close to the danger point.

6. Other factors.

Heavy structures contiguous to excavations greatly increase the tendency to slide or cave, as subway and foundation engineers well know. The wedging off of rock masses by the freezing of water in joints, fissures, and interstices is familiar to all geologists who have studied talus slopes in temperate climates. Earth strains, originating from the variation of barometric pressure and the kneading of tidal pull, should not be ignored in the study of excavation deformations. We are likely to forget that maximum variation of atmospheric pressure near sea level may be over 4,000,000 tons per square mile. So, if the adjustment of atmospheric pressure in a very large cave or mine lagged behind any quick increase in atmospheric pressure at the surface, a very considerable strain would be added to the roof of such excavation.

TYPES OF SLIDE OR DEFORMATION IN CULEBRA CUT.

In Culebra Cut there are four distinct types of slides, or excavation deformation: (1) structural breaks and deformations, (2) normal or gravity slides, (3) fault-zone slides, and (4) surface erosion.

Structural breaks and deformations

General description.—The largest and most important slides develop from structural breaks and deformations. Fortunately, they occur only near Culebra, in a section of the Cut not much over a mile long. These deformations first manifest themselves by the appearance of one or of a set, of cracks or fissures, parallel or somewhat oblique to the edge of the Cut, and from a few metres to some hundreds of metres back from it, and from each other. They may be traceable on the surface for several hundred metres, and they gradually develop into perpendicular crevices up to one-third of a metre wide and many metres dee. The second stage of this phenomenon consists in the settling or tilting of these big blocks formed by the crevices. This movement may consist of a slight and almost even settling (.1 to 1 metre) of the block or blocks, or a tilting of them toward the excavation, or both. If the blocks tilt excavationward, the front part of each sinks with a maximum settlement of about two metres in the front part of the front block. The rear part of each block may come to rest 0—.8 metres above the front part of the block behind it. The third and last stage consists of the dropping downward of any block, due to the failure and squashing out of its base. The whole block then disintegrates and sloughs down into the excavation. This last stage may run its course in from a few hours to a few days. The other two stages may require a few months or more than a year to reach completion. The last two stages are usually accompanied by bulging of the bottom and lower slopes.

Causes.—This type of deformation is due to a primal cause, the unstable geological condition of the materials involved, and an immediate cause, the over-steepness and height of the slopes, the blasting and other work attributable only to man. The first of these depends on several geologic factors, chief among which are: (1) the formations involved are very soft, weak rocks, comprising massive, partly indurated volcanic clays, very friable bedded tuffs and soft, brittle and slippery lignitic shales; (2) these rocks have been further weakened by faulting and by some joint and bedding planes; (3) an abundance of ground-water invades this material whenever it is disturbed by movement or fissuring, and this greatly adds to its mobility; (4) lignitic shale beds, especially where they dip canalward, are planes of weakness along which there is a strong tendency for the overlying material to slip; (5) the presence, too, of a considerable proportion of chlorite particles in the volcanic clay rocks tends to lubricate the mass. The second or immediate cause is chiefly the over-steepness of the slopes where the banks are high and the rocks weak, and the percentage of ground-water is more or less great. The vibrations generated by blasts near these high, overstrained banks are also slide-producing factors. The geological conditions were not sufficiently considered in the first estimates and plans for digging Culebra Cut.

Remedies.—For this type of slide there is but one remedy that has utilitarian value under the conditions involved, and that is now being applied. It consists in making the slopes less steep by removing material from the upper portions, so that the unbalanced pressure toward the foot of the slope will be less than the crushing or deforming strength of the rock involved. Steam shovels are now terracing back the sl[illegible] per side of the Cut and relieving their strained condition. At first [illegible] might seem preferable to let the slides come into the excavation until permanent slopes were reached, thus saving the expense of much blasting. But deformations of this kind weaken the rocks far below the bottom of the excavation, (see Fig. 3) and this weakened material will stand only at a much flatter slope than would have been necessary before it was loosened and weakened by deformative movements. Further, as each block or mass crushes down, it generally leaves behind it not a gradual slope but a steep face 12 to 25 meters or more high, which greatly assists in the generation of other slides. Any deformative movements of slopes should be prevented if possible, because they weaken the rocks and prepare the way for future slides. Then there is the temporary obstruction of railway tracks and drainage ditches caused by some of these slides, which adds to the cost of excavation.

Normal or gravity slides.

The normal or gravity type of slide is due to several factors. Locally along Culebra Cut, porous material lies on top of relatively impervious clay, shale or igneous rock. Rain and ground-water may saturate this porous mass, but are impeded in their downward course by the relatively impervious rock. This causes a muddy, slippery zone to form along the plane of contact between the pervious upper and impervious lower materials. If this plane slopes excavationward, or if there is thrust or head of pressure toward the excavation from higher ground in the rear, a slide of the normal or gravity type may result. Where bedding and joint-planes dip excavationward they greatly assist gravity to wedge off rock masses. This type of slide has certain distinguishing features. The rocks are not deformed or weakened below the plane of actual sliding. The sliding material moves off a solid base, and this base is not pulled down or squeezed out by the frictional pull. Hence these slides are not so destructive as the break-deformation slides are, for they do not weaken the slopes, but disturb only the material which slides. Ordinarily no saving of excavation can be accomplished by removing material from the upper parts of such slides. It is better and cheaper to let them run their course and remove them from the bottom of the Cut. Drainage is almost the only remedial factor that can be applied to them. The Cucaracha slide, which has been active at intervals since the French Company began operations, is the worst example of this type. The Cut is now practically down to grade in front of this slide, so it has reached its last important stage of activity.

Fault-zone slides.

The third type of slide is that occasioned, primarily by the weakening effects of sheared fault-zones which cut diagonally across the Canal prism. These are in some cases assisted by a weak layer of rock near the toe of the slope. In these slides the mass of rock in the acute angle, which the fault-plane makes with the plane of the excavation wall, has in some cases a large overhang due to the dip of the fault. This overhang rests insecurely against the fault-plane, thus throwing an additional strain on the whole block. As the excavation is deepened this strain increases and, if the base of the block collapses, a fault-zone slide results.

Two large slides of this type have occurred on the east side of the Canal.

Fig. 4. La Pita Slide.

(a) More important fault plane which greatly weakened the rocks and through which water seeped from the diversion ditch. (b) Smaller fault plane which also weakened the rocks. (c) Location of the diversion ditch. (d) Breccia: comparatively strong rock. (d') 20,000 cubic yards of rock which crushed down. (e) Volcanic agglomerate; the rock which failed, due to the above indicated fault zones, to the weakening effect of seepage along the fault zone and, in less degree, to the steepness and height of slope.

between Empire and Las Cascadas. In the case of the La Pita slide (Fig. 4), a strong andesite breccia (*d*) covered a much weaker volcanic agglomerate and lava-mud flow (*e*) to a depth of 60 feet, the whole forming a steep wall 90 feet high. A major diagonal fault-plane (*a*) with an excavationward dip of 65°, and a minor fault-plane normal to the horizontal and to the axes of the Canal, were the chief weakening factors. Water from a diversion ditch at *c* seeped down along the fault-plane, and helped soften the already weak volcanic agglomerate (*e*) until it failed. The final result was that 20,000 cubic yards of rock crushed down and had to be removed. Another slide (Fig. 6) a little north of this let down 300,000 cubic yards under practically similar conditions.

The fault-zone type of slide, unlike the others, occurs in rocks strong enough to stand at a steep slope but for the weakening effects of diagonal, canalward sloping faults, which leave overhanging parts of large rock masses resting insecurely against slippery fault-planes. Slides of this character are not common and are remedied by lessening the slopes in the vicinity of these fault-zones, and where practicable by preventing excessive water from seeping into them. There might be cases where it would pay to reinforce these weak zones with steel and concrete work, to prevent initial motion; but no such case came to notice in the work here.

Sliding ground due to erosion or wash.

The soft and easily weathered rocks of Culebra Cut are much trenched and washed by heavy rains, where they slope steeply and are unprotected by vegetation. The reasons for the rapid weathering of these rocks have already been explained (page 783). Each heavy rain removes the disintegrated soil from the slopes of the excavation, leaving fresh surfaces exposed for further weathering action. It is estimated that the sediment washed into Culebra Cut in this way would cover the bottom to a depth of two inches or more each year, or something over 65,000 cubic yards. At 25 cents per cubic yard for dredging, this would add over $16,250.00 per year to maintenance charges. Fortunately the luxurious growth of vegetation which characterizes the region provides a remedy. These slopes will suffer relatively little erosion, when carpeted with grass and shrubs. It has, therefore, been proposed to promote the growth of vegetation on the permanent slopes of the Canal where necessary. Such vegetation will have no effect on the large slides, but it will minimize the wash from heavy tropical rains.

Another large erosion problem, where the rocks are soft, results from the wash of steamers. Any protective covering, used to obviate this, will have to be designed with some understanding of the geological conditions of the rocks which it is to protect. For instance, the rocks will swell somewhat with oxidation, and they will crumble a little wherever ground-water can leach out their soluble salts. There will also be some slight adjustive movements, as time goes on, created by the new conditions of rock pressure. All of these movements will be different, as the character of the rock varies from place to place.

APPROXIMATE SLOPES TO MINIMIZE SLOUGHING, DEFORMATION AND EXCAVATION.

Before concluding this paper I shall set forth what, in my opinion, are about the best excavation slopes to adopt for different kinds of material. Of course, the character of material cut by excavations varies over a wide range, from the toughest granitic rocks, on the one hand, to mud on the other. Theoretically, then, the slopes should vary from perpendicular to almost horizontal. Because of varying conditions, it is nearly impossible to set down the exact figures to which slopes should be made to conform for security and minimum excavation. Those given herein are based largely on observation of railway cuttings and mountain and cañon slopes in Central America and in the United States. These figures are not by any means final, and any discussion that they may cause will be welcomed as the first step in the best way to gather more information on the subject. It is hoped that the engineer and the geologist may thus be aided in estimating the distance from any excavation to which deformations are likely to extend; and also that it may furnish more data for estimating the cost of excavations in different kinds of materials.

The following different type conditions under which rocks will slough, but will not flow are postulated. In cases which fall between these, interpolation will supply the corresponding configuration of slope.

1. Given solid rock of relatively high crushing and tensile strength, with a minimum of jointing, fissuring, and bedding. This would include granitic and trap rocks, quartzites, solid sandstone and shales, in fact most of the hard, relatively tough rocks that have very little jointing, fissuring and bedding. An excavation in such material should have a slope of about 10 on 1 (meaning 10 units up and 1 unit over). Slopes in such material might be left perpendicular, but for the fact that blasting leaves the rocks somewhat fissured, and a very small slope greatly aids in preventing sloughing. Even where the slopes are channeled, weathering after a time opens up small cracks, not recognizable in the fresh rock, and from these small masses are liable to slough as time goes on.

2. Given the same kinds of rock as described in **1**, but with jointing and fissuring increased to about the average of that commonly encountered in excavations, or the average common to the kinds of rock described under **1.** The slope of an excavation under such conditions should be about 7 on 1.

3. The same rock as in **1** and **2**, but with the jointing and fissuring increased to the maximum of that encountered in nature in such rocks. For such the slope should be about 3 on 1.

4. Wherever an excavation parallels bedding- or fault-planes which dip toward it, the rock being the same as that mentioned in **1** and the jointing corresponding to that described under **2** or **3**, then the slope is likely to be controlled by such bedding- or fault-planes, as follows:

(a) Where the individual beds are a metre or more thick, and where no clayey or slaty rock has formed along the bedding- or fault-planes, about 2 on 1 would be a safe slope.

(b) Where the rocks are thinly bedded and where shaly, clayey or slickensided conditions prevail along the bedding- or fault-planes, then 2 on 3 would represent about the maximum flatness necessary for the slope. Where the bedding is not rendered slippery by clay partings, a 1 on 1 slope would be quite safe.

5. It may be recalled that the maximum angle of slope of sand dunes is about 1 on 2, which is practically the angle of repose for dry sand.

The above conditions pertain only to the rocks described, which will not crush or deform by flowage toward an excavation, but will only slough off fragments and masses loosened by fractures, jointing, bedding, faulting or other causes. Under these conditions the slopes should all be approximately plane surfaces, except in the upper part, where the material is much weathered and changed into soil. Here erosion will remove some of the soft material and will tend to give a curved surface. The plane surface of the lower part of the excavation will then be tangent to the curved surface of the upper weathered material, and this latter surface will approach logarithmic curvature.

APPROXIMATE SLOPES UNDER CONDITIONS OF FLOWAGE AND FRACTURE

We now come to consider the best slopes to adopt where excavations cut rocks that will deform by flowage, as well as by fracture. In such cases an entirely new set of conditions enters into the problem, because deformations or movements may extend to some depth below the excavation, as well as to considerable distances from it horizontally. The well-known case of swelling ground in tunnels, especially in certain coal mines, is a manifestation of this variety of rock deformation. As already explained in this paper (page 782), certain rocks may stand at a very steep angle until the excavation which they overlook reaches a depth of say 20 to 30 metres or more; then they may begin to deform and later to slide, until a very flat angle is reached. For such rocks the slope which will minimize the danger of deformation and give maximum steepness and utility will be a curved surface, instead of the plane surface which suffices for the more stable rocks. The reasons why it should be a curved surface are: (1) earth pressures, against a retaining wall, for instance, vary as the square of the height of the wall; (2) with increase of depth ground-water becomes more active in penetrating and softening rocks and in dissolving out cementing material from them; (3) gravity stresses, helped by ground-water and the element of time, cause slight movements and swellings in the rocks, and every such movement is an added weakness to the slope. Hence, if for any cross-section of an excavation, especially in soft rock, the different depths were used as abscissa, and the corresponding tendency to deformation at that depth as ordinates, the plotted result would be a curve.

The following are given as approximately the best slopes to adopt for excavations in the materials described. A theoretical slope should first be determined on according to the depth of the excavation, character of rock, etc., from the tables which follow. Then a cross section of that slope and the bottom plane of the excavation, should be plotted. A hyperbola tangent to these two, with its vertex in the projection of the bottom plane, will represent about the proper slope and curvature for the excavation. In all excavations, allowance must be made for the fact that the soft decayed rock and soil material near the top, will tend to erode back from the excavation until the surface approaches logarithmic curvature. The following are the different kinds of rocks, with slope-tables for each at different depths: (see table, page 792).

A. Certain fairly soft and weak sandstones, shales and a few limestones; also a few soft tuffs, agglomerates and clay rocks,—rocks which will deform under great pressure but which will deform relatively slowly. Under this heading come most of the rocks that cause swelling ground in coal mines and other excavations, but which are stronger than the clay rocks and tuffs of Culebra Cut.

B. The same rocks as A, but with medium shearing and jointing.

C. The same rocks as in A and B, but with jointing, fissuring and shearing increased to the maximum for such rocks. Also those in which the bedding may dip toward the excavation.

D. Soft volcanic-clay rocks, bedded friable tuffs, lignitic shales; rocks similar to the Culebra and Cucuracha formations in Culebra Cut. These are the rocks in which most of the big slides have occurred. Such rocks have a high content of water, and contain considerable chloritic material. They are ordinarily very fine to medium grained, and may contain thin beds of partly cemented gravel, and some lenses of soft sandstone and brittle limestone. These rocks are first considered as having a minimum of jointing, fissuring and bedding.

E. The same rocks as in D, but with jointing, fissuring and bedding increased to the average for such rocks. About equivalent to the conditions in Culebra Cut, except in a few localities where the Culebra Cut rocks have been excessively sheared by faulting.

F. The same rocks as in D and E, but with jointing, fissuring and bedding increased to the maximum. Under this heading would come the local areas in Culebra Cut that are crushed by faulting.

G. Any extremely soft rocks that are much crushed and rendered mobile and slippery by ground-water, talcose clays, etc. Most of the ground that is in motion toward Culebra Cut. Most sliding material already moving.

TABLE OF SLOPES TO ADOPT AT DIFFERENT DEPTHS FOR ROCK CONDITIONS DESCRIBED ABOVE

Depth of Excavation		A	B	C	D	E	F	G
Feet	Metres							
33	10	50 on 10	40 on 10	30 on 10	20.0 on 10	12 on 10	7 on 10	5 on 10
66	20	41 10	33 10	25 10	17.0 10	10.3 10	6.1 10	4.2 10
98	30	36 10	28 10	21 10	15.4 10	9.3 10	5.6 10	3.6 10
131	40	32 10	25 10	19 10	14.4 10	8.6 10	5.2 10	3.2 10
164	50	29 10	22 10	16 10	18.5 10	8.0 10	4.9 10	2.8 10
197	60	26 10	10 10	14 10	12.7 10	7.5 10	4.6 10	2.5 0
230	70	24 10	18 10	13 10	12.0 10	7.2 10	4.4 10	2.2 10
262	80	23 10	16 10	12 10	11.4 10	6.8 10	4.2 10	2 0 10
295	90	21 10	15 10	11 10	10.8 10	6.5 10	4.0 10	1.9 [illegible]
328	100	20 10	14 10	10 10	10.2 10	5.2 10	3.9 10	1.8 10
361	110	18 10	13 10	9.8 10	0.5 10	6.0 10	3.8 10	1.7 10
394	120	17 10	12.5 10	9.3 10	8.7 10	5.9 10	3.7 10	1.6 10
427	130	16 10	12 10	9 10	8.0 10	5.8 10	3.6 10	1.5 10
459	140	15 10	11.5 10	8.8 10	7.4 10	5.6 10	3.5 10	
492	150	14.5 10	11 10	8.6 10	6.8 10	5.5 10	3.4 10	1.4 10
525	160	14.0 10	10.8 10	8.4 10	6.5 10	5.4 10	3.3 10	
558	170	13.5 10	10.5 10	8.3 10	6.3 10	5.3 10	3.2 10	1.3 10
591	180	13.0 10	10.3 10	8.2 10	6.2 10	5.2 10	3.1 10	
623	190	12.5 10	10.1 10	8.1 10	6.1 10	5.1 10	3.05 10	
656	200	12.0 10	10.0 10	8.0 10	6.0 10	5.0 10	3.0 10	1.2 10

Note.—The slope given for each depth in the above table is to extend from the bottom to the top of the excavation at the same angle (plus hyperbolic curvature tangent to the slope and bottom, as already explained). If an excavation is 200 metres deep in class A rocks, its slope is to be 12 on 10, plus curvature, from bottom to top, and not 50 on 10 for the first ten metres, 41 on 10 for the second, and so on.

Heavy blasting should not be used right up to the completed slopes, if they are to stand at the angles given above.

When ground once begins to deform, the angle at which it will stand will be very much flatter than that at which it would have stood before movement set in.

In any given excavation the weakest rock encountered will govern the slope for that excavation.

DISCUSSION.

E. DE MARGERIE (Paris) rappelle que des conditions analogues à celles que présentent les tranchées du Canal de Panama ont été rencontrées, dans la première moitié du siècle dernier, par les ingénieurs français chargés de construire le Canal de Bourgogne. La traversée des plateaux de la Côte d'Or offre, en effet, une épaisseur considérable d'argile et de marnée d'âge jurassique, dont les mouvements ont souvent contrarié les travaux. Dès 1840, dans un mémoire remarquable, Colin a analysé avec rigueur la marche du phénomène; il ne semble pas que son ouvrage, intitulé *Recherches sur les glissements spontanés des terrains argileux*, ait trouvé auprès des géologues et des géophysiciens l'accueil qu'il méritait.

NOTE ON LANDSLIDES.[1]

BY

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With such gentlemen before me as Dr. ERNEST HOWE, geologist to the first American Panama Canal Commission, and Dr. BECKER, consulting geologist of the United States government with respect to the canal, I naturally feel much hesitation in making any remarks based upon the notes of only a few days spent in the great excavation. Nevertheless, I wish to offer some observations in discussion of the paper presented by Mr. DAHLBLOM.

The angle of pull, geologically considered, is the complement of the angle of repose, and it is of geological importance in so far as it effects the distribution or redistribution of rock material.

Among others PENCK in his *Morphologie der Erdoberfläche* has discussed the theory of landslides, while HOWE in his United States Geological Survey paper on the San Juan mountains, Colorado, has given an elaborate description of a restricted area that is particularly adapted to an intimate study of the phenomena accompanying slides, and PATTON has given additional illustrations from the Rocky mountains of the geological importance of dry-rock slides. The great landslide which occurred a few years ago at Frank, Alberta, has already been cited by Mr. DAHLBLOM.

On account of the economic importance and engineering magnitude of the Panama canal, the slides in the Culebra cut are particularly interesting. They have been divided into three classes:

1. The simple slipping of an incoherent bank into the canal prism as a direct result of the removal of side support, just as a boxed cube of sand would spread out until it reached the angle of repose on the removal of the sides of the containing box.

2. The bodily horizontal movement into the prism of a coherent bank resting upon a bed of shale when this bed was intersected by the digging, the shale acting as a good lubricant. Slides of this kind have taken place where the underlying shale beds dip toward the canal. Contractor's hill, on the west bank of the deepest part of the cut, would slide into the prism were it not for the fact that its basal soft beds dip away from the canal.

3. The vertical rising of the bottom of the prism resulting from the disturbance of equilibrium caused by the removal of material from the canal, the downward pressure of a coherent bank being transmitted horizontally

[1] In discussion of *The Angle of Shear*, by Th. DAHLBLOM.

through soft shale under the bottom of the canal and then upward where resistance had been lessened.

Several phases of the first class may be seen in Culebra cut, depending upon the nature of the material intersected, whether sandstone, shale, limestone, volcanic breccia, or massive igneous rock. In every case, however, the influence of the jointing of the mass, taken into consideration with the cohesion of the rock itself, has been of the highest importance in determining whether sliding would take place with a given height of unsupported new face or not.

The famous Cucaracha slide occurred in a so-called hardened "lava-mud" or breccia, jointed to the highest degree. This jointing had permitted infiltration of the copiously supplied atmospheric water to every part of the rock mass, reducing its cohesion, lessening the coefficient of friction between its component particles, not only through the presence of the water itself but also through the formation everywhere of slippery alteration products, and resulting in a veritable mud which has not come to rest even on a slope of one to seven.

The steepness of the natural slopes in tropical regions has been noted by many observers. It was strikingly evident in Martinique and St. Vincent when the volcanic eruptions of 1902 stripped vegetation and surface soil from the sides of Mount Pelée and the Soufrière. Canyon-walls scores and even hundreds of metres high were seen to be stable at angles of 65° to 85° from the horizontal, though carved from loosely consolidated ash. Extensive minute jointing, however, seems to be absent and the rocks are more acid in nature than those of the Panama peninsula. The former are therefore more resistent to alteration and their alteration products are less greasy than those of the latter. The character of an igneous rock is a geological factor that an engineer must take into consideration, as well as its jointing, when he seeks to determine the liability of slides in connection with his work.

As is well known, earthquake shocks may be an exciting cause in the production of landslides, but although the shattering action of the eruptions at Mount Pelée and the Soufrière, particularly the latter, was extreme, no landslides were caused thereby except in the crater walls and, at St. Vincent, in loose shore deposits at the base of the mountain. The engineers of the Culebra cut blame the heavy blasting there for starting some of the slides that have caused them so much trouble. There can be no doubt that the blasting has produced some shattering effect backward into the country rock, as well as forward into the canal prism, thus adding to the fissuring that admits water to the rock mass. The blasting has likewise probably had some "trigger" effect in disturbing the equilibrium of the unstable walls of the canal as noted by Dr. Howe.

In connection with this trigger action, I wish to cite personal observations made during the summer of 1912 on the seismograph at the American Museum of Natural History in New York City. The instrument is a large-model Mainka pendulum with steady masses of 450 kg. each, damped about $\frac{3}{4}$, geared to a magnification of about 200. Its concrete pillar rests upon and is cemented to the edges of nearly vertical laminæ of Pre-Cambrian mica-schist. Much blasting with dynamite was done by contractors in excavating for the basement and foundation walls of an addition to the Museum building. The shocks naturally were not on the scale of those in the Culebra cut, but they originated at from 20 to 50 metres from the seismograph. With one exception they caused a vibration of the recording needle of a single half wave-length with an amplification of from ½ to 1 mm., varying with the distance and the angle of transmission with reference to the lamination of the schist.

The exception was a blast exploded only 5 metres from the seismograph pier along the strike of the supporting schist. This shock caused a swing of about 25 mm., throwing the needle off the paper and indicating an absolute wave movement of .12 to .15 mm. in the rock at this distance from the blast.

The heavy blasting done in driving an aqueduct tunnel 5½ metres in diameter, approximately 400 metres distant from the seismograph, across the strike of the schist has produced no perceptible effect upon the recording apparatus of the instrument.

An oil tank explosion in Bayonne, N.J., in the summer of 1912, was felt as a great shock by thousands of people in the high office buildings in lower New York City, 9 kilometres distant, where it shattered hundreds of windows but produced no perceptible effect upon the Museum seismograph 18 kilometres distant, although the wave motion would have arrived along the strike of the schist.

The vibratory effect in a rock mass due to blasting is limited in extent and transitory in value and seems hardly adequate to act as a trigger to start great landslides, except in its immediate proximity; but an interesting subject of study is opened up for investigation through the use of shock-recording instruments in tunnels, mines, quarries and other excavations where heavy blasting is going on. The Japanese have gone deeply into this phase of seismology.

DISCUSSION.

H. F. REID (Baltimore). Dr. Hovey's observations are confirmed by the experience of others. The amount of energy liberated by an earthquake is enormously greater than that liberated by any artificial disturbance. The seismograph at Ancon has not recorded the heavy blasting 20 or 25 miles away. The seismograph at Baltimore, at a distance of 200 feet from the Baltimore and Ohio railway tunnel, does not record the passing of trains (the magnification is only 6), although it does record all the great earthquakes however distant their points of origin.

MINING SUBSIDENCE.

BY

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This is a subject of considerable importance to geologists and mining engineers, and is one which directly or indirectly affects all owners or users of land in mining districts; yet, comparatively speaking, very little is known at present regarding the results likely to be effected under any given system of working.

In some of the deeper mines in Great Britain, where the lower seams have been extracted in advance of the upper ones, it has been observed that the fractures in the upper seam caused by the strata subsiding into the mined area below, slope forward over the solid coal at varying angles depending on local conditions.

Fig. 1 shows an example in the Ayrshire coalfield where a six-feet seam was worked out before the upper four-feet seam was started. Although the distance separating the seams is only about 90 feet, the factures in the four-feet seam were inclined forward at an angle of about 150°, whereas the roof

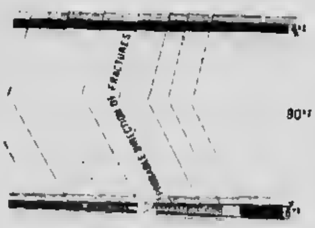

Fig. 1.

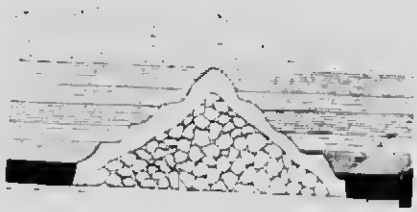

Fig. 2.

fractures in the lower seam sloped backward towards the worked-out area, as shown. From this it would appear that the nether roof which breaks back towards the goaf is very thin (see Fig. 2).

In other districts—particularly urban areas—where careful levelings have been regularly carried out, it has been noticed that the subsidence is always projected in advance of the working faces at distances varying from one-tenth to two-thirds of the depth from the surface, as shown in Fig. 4.

In this short paper the writer does not pretend to put forward a theory to explain the relationship between "*subsidence*" and the "*angle of pull*" (or draw), but merely to record several observed phenomena and deductions made from them, which may form a basis for discussion of the subject.

There are several points which may be considered sufficiently well established to form a basis for further investigations, e.g.,

(a) That surface subsidence invariably extends over a greater area than that excavated.

(b) That the *angle of pull* is determined by the ratio between the excavated and subsided areas.

(c) That this ratio is determined by a large number of factors, among which may be included the following:—

1. The amount of permanent support left in the mined area.
2. The thickness of the seam (etc.) worked.
3. The depth of workings from the surface.
4. The method of working adopted.
5. The direction of working in relation to the jointing of the strata.
6. The rate at which the workings advance.
7. The nature of the strata overlying the workings.
8. The presence of faults, fissures, etc., in the strata.
9. The permeability of the overlying rocks.
10. The dip of the strata.
11. The surface contour.
12. The potential compressive forces existing in the strata containing the workings.

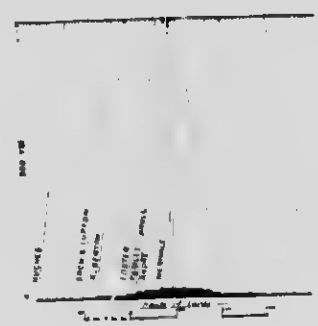

Fig. 3.

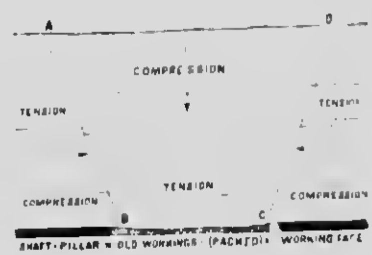

Fig. 4.

It is evident that the number of factors which govern the relationship between subsidence and the angle of pull make it exceedingly difficult to find exactly similar conditions, from which similar results might be expected. Where the physical or geological conditions are identical, the method of working, packing, etc., may be different, and vice versa.

This is very apparent in mining engineering, where formulæ devised by mining engineers to find the size of shaft pillars (probably obtained from actual experience in some particular district) are so varied in their results as to be useless as a guide to others.

Fig. 3, shows diagrammatically the results obtained from six different formulæ, from which it will be seen that the variation between MERIVALE'S rule and that of HUGHES is 11 to 1 for a six-feet seam at a depth of 600 yards from the surface.

Assuming as is frequently done, that the angle of pull in horizontal strata is only 8° from the vertical, the dotted lines indicate the position of the plane of strain, which in the case of the four smaller pillars would cut into the shaft. If the area on the surface to be protected (c) is, say, 200 yards in diameter, the fifth and sixth are also too small, while that of HUGHES is evidently too large.

This example is sufficient to show the necessity for a closer study of the question of subsidence if satisfactory results are to be obtained. Examples could also be quoted to show that, owing to the influence of dip on the angle of pull, pillars of support have often been left in the wrong place.

To obtain brevity of expression in referring to the phenomena associated with subsidence, and to prevent misconceptions regarding the meaning of the terms used, the writer has adopted the terms defined by Mr. H. W. G. HALBAUM in his paper, *The Great Planes of Strain in the Absolute Roof of Mines*,[1] and illustrated in Figs. 4 and 5, as follows:—

"*Mined strata*"—the subcylindrical column of strata (ABCD) Fig. 4, the perimeter of which is the excavation proper.

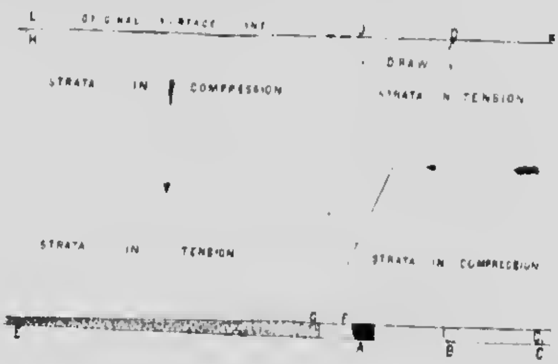

FIG. 5.

"*Dead zone*"—the portion of mined strata which has settled through the maximum subsidence; behind HE, Fig. 5.

"*Motive zone*"—the portion of mined strata still in process of sinking; HEFJ, Fig. 5.

"*Littoral zone*"—the disturbed strata immediately in advance of the "mined strata"; JFBD, Fig. 5.

"*Prime strata*"—the strata immediately in advance of the "littoral zone"; DBCK, Fig. 5.

"*Absolute roof*"—the entire body of overlying strata.

"*Nether roof*"—the short depth of roof immediately above the workings that timber might be expected to support.

[1] Trans. Inst. Min. Eng., 1906, Vol. XXX, p. 176.

"*Vertical face*"—the vertical plane of the line of working face in longwall, or the goaf-line in bord and pillar workings; JF, Fig. 5.

"*Prime face*"—the conterminous face of the littoral zone and prime strata; F D, Fig. 5.

"*Stress*"—the intensity of the force.

"*Strain*"—any alteration of figure produced by the application of force.

"*Draw*"—the horizontal measurement of the littoral zone (at the sursurface); JD, Fig. 5.

"*Subsidence*"—the vertical measurement of the displacement of the motive zone; LH, Fig. 5.

"*Angle of pull*"—the angle between the vertical and prime faces; JFD, Fig. 5.

When excavations are made at the surface, as shown in Fig. 6, the walls of the trench, even in comparatively hard strata, always tend to move towards the centre of the excavation (AB to EB and CD to FD), due to the liberation of potential forces stored up in the earth's crust through secular

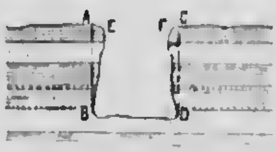

Fig. 6.

Fig. 7.

cooling. If the strata is soft a greater movement will be effected, the strata moving into the excavated area until the "angle of repose" is reached.

When an excavation is made underground by the removal of a layer of coal or other rock, two potential forces are liberated. One of these forces, due to gravity, is acting vertically downwards (Fig. 5) at an approximate pressure of one pound per square inch per foot in depth; the other is acting horizontally, and is projected against the former in a direction opposite to that of the workings forming the excavation.

It has been frequently noted that where the vertical force is allowed to act rapidly the strata forming the nether roof break through in the form of small slip-faults (as shown in Fig. 1) with a maximum amount of subsidence and the angle of pull only a few degrees from the vertical. If, on the other hand, the vertical mass subsides slowly, without fracturing the nether roof, the angle of pull is increased and the subsidence reduced.

As the two forces referred to are acting towards the excavated area, forming planes of strain (FD, Fig. 5) sloping forward over the solid face of the workings, it is evident that the ratio of vertical to horizontal movement produced determines the angle of pull. If the subsidence is a maximum the angle of pull will be a minimum and vice versa, because the greater the subsiding surface for a given area of excavation, the less subsidence must there be.

The numerous causes which determine subsidence and angle of pull account for the very varied results noted by observers in different mining districts.

Mr. J. S. Dixon[1] gives examples where the draw varied from one-eighth to two-thirds of the depth of the seam from the surface, which equals 7⅛° to 33¾° angle of pull.

Mr. J. P. Kirkup[2] noted that the relative draw was one-quarter to one-third of the depth, which equals 14° to 18½° angle of pull.

Mr. J. Piggford[3] gives 16° as the angle of pull.

Mr. W. Hay[4] gives the draw at Shirebrook colliery at 240 to 300 feet at a depth of about 1,700 feet, which is one-seventh to three-seventeenths of the depth, and equals 8° to 10°.

Mr. H. T. Foster[5] gives the angle of pull at 31½° in a seam dipping 5½° with the workings on the strike.

Fig. 8.

Fig. 9.

The reason for the difference in the results quoted may be partly explained by taking the factors (1 to 12 previously enumerated as determining the angle of pull) in the order given.

1. *The amount of permanent support left in the mined area.* This has considerable effect in determining the amount of subsidence and angle of pull as shown in coal-mining areas, particularly where the angle of pull is practically proportional to the efficiency of the packing put into the excavated area.

In horizontal seams where the coal is extracted by the longwall process of working, the angle of pull may be as low as 8° (from the vertical), whereas if efficient hand packing is adopted the angle of pull may be increased to over 30°.

According to Dr. Neiss,[6] when packs were made with small-grained pit rubbish the roof subsided 25 per cent. of the thickness of the seam; when

[1] Trans. Min. Inst. Scotland, 1885, Vol. VII, p. 224.
[2] Trans. Inst. Min. Eng., 1904, Vol. XXVIII, p. 320.
[3] Trans. Inst. Min. Eng., Vol. XXXVIII, p. 129.
[4] Trans. Inst. Min. Eng., Vol. XXXVI, p. 427.
[5] Trans. Inst. Min. Eng., Vol. XXXIV, p. 407.
[6] Zeitschr. f. Berg., Hütt.-u-Salinenw., 1910, Vol. LVIII, p. 119.

made with pure sand about 8 per cent.; and with sand flooded in a semi-fluid state (hydraulic packing) complete immunity from subsidence may be obtained.

Herr BUNTZEL,[1] giving particulars of 14 instances of packing old workings with sand, clay, ashes, etc., in a semi-fluid state, says that the subsidence is comparatively small in degree, varying from 0.3 per cent. to 7.8 per cent. of the height of the seam (as compared with 30 per cent. to 70 per cent. where the roof was allowed to fall in). What subsidence did take place occurred without fracturing the strata and the angle of pull was greatly increased.

It is evident that the greater the percentage of débris put into the mined area the less movement can take place in the absolute roof, thus keeping the latter whole and "drawing" for longer distances over the solid workings.

In many of the examples of subsidence recorded it has been noted that when the strata in the absolute roof become fractured these fractures increase in width as the workings advance towards them, reaching the maximum (2 inches to 3 inches in some cases) when the working faces are immediately below, and closing up again as the workings advance beyond them, as shown in Fig. 5. The nearer to the vertical these fractures take place the wider they become, doing a considerable amount of damage to surface property. As the angle of draw increases the fractures decrease in width and subsidence

FIG. 10.

FIG. 11.

takes place so slowly that even though large buildings become slightly tilted on the approach of the workings they will right themselves again without serious fracture when the workings have passed beyond them.

2. *The thickness of the seam worked.*—In thick seams, even if as efficiently packed as thin seams (which is seldom the case, owing to the difficulty of providing sufficient packing material), the total subsidence is increased and the angle of pull is small. As the workings advance slowly and usually irregularly (owing to the method of working adopted), the tendency to fracture the absolute roof is great. The fractures produced are usually very wide and, the prime face being nearly vertical, this allows the force in the motive zone to exert itself rapidly and often in a jerky fashion, suddenly breaking off pieces of the nether roof. This is probably why the accident rate is us-

[1] Zeitschr. f. Berg., Hütt.-u.-Salinenw., Vol. 1911, LIX, p. 293.

ually two to three times as high in thick seams as it is in thin seams, in this country.

3. *The depth of workings from the surface.*—In shallow workings subsidence usually takes place suddenly, the subsiding surface being very little larger than the excavated area, owing to the angle of pull being small. Even if the prime face remained at the same angle it is evident that, as the depth increases, the subsiding area at the surface increases for the same area of excavation, as shown in Fig. 8. The angle of pull is likely to increase with increased depth, owing to the draw of the littoral zone against the motive zone assisting to support the absolute roof and allowing it to sink gradually in a slightly curved form without fractures.

4. *Method of working adopted.*—In longwall workings, where the coal is completely extracted in one operation, subsidence (varying according to depth from the surface, thickness of seam, efficiency of packing, etc.) usually takes place along planes parallel to the working faces, but some distance in advance of them.

In bord and pillar workings, where the line of faces on the pillars being extracted may be very irregular and where the roof is usually allowed to fall

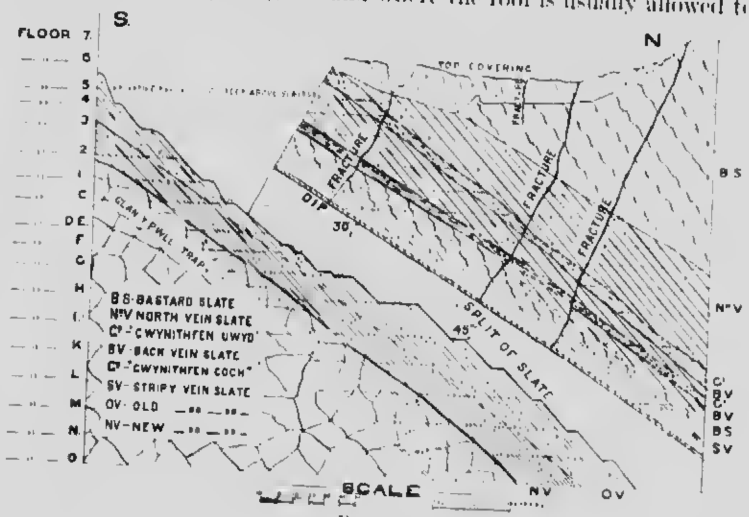

FIG. 12.

in as the pillars are taken out, the subsidence is increased and irregular in form. If, however, subsidence does take place along planes parallel to the jointing of the rocks, a large amount of the coal in the pillars is lost through excessive crush. If the pillars are made too small the weight of the absolute roof crushes them into the floor, forming incipient fractures which may pass for long distances up through the strata. Any movement of this description increases the subsidence when the pillars are being extracted.

5. *Direction of working.*—This will also have a distinct bearing on the relationship between draw and subsidence, particularly in districts where

the strata are widely jointed. If work is prosecuted parallel to the "cleat," or jointing, subsidence will be greater than when it is carried on at an angle across the joint planes, because fissures will be more readily produced in the former case.

6. *Rate at which workings advance.*—Where workings advance rapidly the tendency will be for the strata to bend without fracturing; whereas if the opposite is the case, the force of the motive zone has time to break through, as is frequently shown on the working faces after a prolonged stoppage due to holidays or strikes.

7. *Nature of overlying strata.*—As the angle of pull under normal circumstances might be expected to approximate to the angle of repose for any particular series of rocks, the softer the beds the greater the angle of pull that should result. In mining this is not usually the case where the overlying strata consist of very thick, hard layers of sandstone: the angle of pull is invariably larger than where the strata are soft.

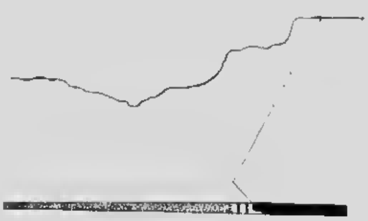

FIG. 13.

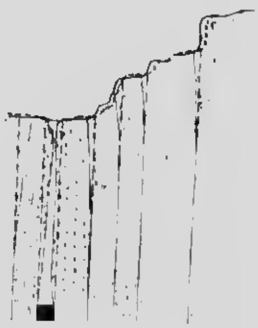

FIG. 14.

This may be due to the rapidity of the action of subsidence in soft rocks and to lack of cohesion between the rock particles permitting sudden changes of strain to take place by fracturing.

Thick sandstone layers will bend for considerable distances without breaking, pulling over the solid coal for great distances, and often pulverizing the coal by excessive crush (Fig. 7).

8. *Presence of faults and fissures.*—In the presence of faults the subsiding strata tend to draw into the hade of the fault, which, if flat, greatly increases the angle of pull. The result of the great pressure thus produced on coal seams in the vicinity of faults is shown by the number of spontaneous gob-fires which have taken place under such conditions in seams liable to spontaneous combustion.

It has also been frequently noted that when working under the usually badly fissured Magnesian limestone in Yorkshire, Northumberland and Durham districts, the angle of pull is very frequently increased when approaching the limestone.

9. *Permeability of the strata.*—Strata heavily charged with water will

no doubt move more rapidly than dry strata, on account of the lubrication afforded by the water. Some engineers, on the other hand, have suggested that the draining of wet ground by underground mining operations tends to increase the subsidence, which would as a result reduce the draw.

10. *Dip of strata.*—The angle of inclination of the strata plays a very important part in determining the ratio between subsidence and draw.

In flat workings the weight of the vertical strata composing the absolute roof will by force of gravity tend to force the under roof into the excavation, producing maximum subsidence with minimum draw. In vertical workings the maximum movement will be in the direction of draw, as the strata on either side of the excavation are still supported by the strata immediately underneath; hence the "caving" in of the walls will be the result of horizontal pressure, assisted by the beds assuming the angle of repose.

In degrees of dip varying between the horizontal and vertical the subsiding or "drawing" movements will be largely determined by the dip, as the amount of support afforded to the absolute roof by the solid strata underneath will affect the gravity pull, which decreases as the dip increases (see Figs. 5 and 9).

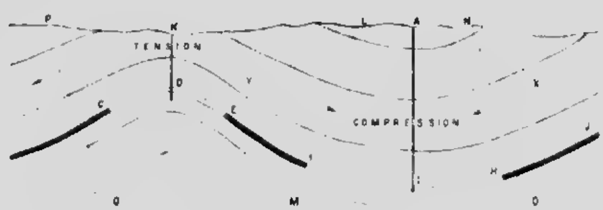

FIG. 15.

Here again the practice of leaving pillars in coal mines to support surface property, on the assumption—which is frequently made—that at all dips over 24° the angle of pull is vertical, has resulted in considerable damage.

Even at a dip of 24° it is hardly possible to imagine mined strata coming to rest on the prime face (Fig. 10, XY). It is less likely that the prime face will be vertical where the dip is greater than this, as shown in Fig. 11.

It appears to the writer that in excavations made in fairly hard rocks the tendency would be for the angle of pull to increase regularly from the horizontal position (Fig. 5) to the vertical (Fig. 9), where almost the whole of the disturbance results in draw. Fig. 12 is an example of subsidence in inclined strata at the famous Oakeley slate quarries, Blaenau Festiniog, North Wales, in which the fractures appear to be almost at right angles to the dip of the strata.

11. *Surface contour.*—It is a well-known fact that, where the surface is irregular, the greatest disturbance on the surface resulting from mining operations takes place on steep slopes. This is no doubt due to the influence of draw as shown in Figs. 13 and 14, where the dotted line indicates the original surface contour.

Rapid horizontal movement on a large scale in surface rocks has a more disastrous effect than subsidence, so far as buildings are concerned, for usually the rocks become badly fractured and in many cases landslips result.

12. *General geological structure of the absolute roof.*—In strata which have been compressed into synclinal and anticlinal folds by earth movements, the action of the subsiding mass will be different from that of horizontal strata.

A coal seam worked from G to H or F (Fig. 15) would produce ratios of subsidence and draw quite different from that worked from D to E or C. The amount of potential energy stored up in the absolute roof in the form of compression will be greater in the former than in the latter, therefore subsidence would be less, and draw greater, on FH than on CE.

The joints are more likely to be wider and small faults or fissures more frequent in the latter case, which would also increase the subsidence; but on the other hand, the direction of the joints (PQ) might to some extent counteract this as compared with those at ML or ON.

SUMMARY.

The ratio between subsidence and draw must be the joint result of the forces liberated by the withdrawal of support from underneath the strata in the mined area. The larger the proportion of settlement resulting in subsidence the less can occur in the form of draw, and vice versa.

Sudsidence will be at a maximum in flat seams and draw at a maximum in vertical seams.

The more effective is the packing the less the amount of settling that can take place either as subsidence or draw, and as the settlement would be likely to occur slowly the strata would bend without fracturing.

Where fracturing does occur, the change of strain in the rock particles in that portion of the strata which is leaving the littoral zone and passing into the motive zone will be rapid, producing noises known among miners as "bumps," "thuds," "crumps," "bowks," etc., and which are usually accompanied by sudden falls of roof and side.

The number of factors that may influence the results produced by the settlement of mined strata is so great that only a wide and comprehensive inquiry by geologists and mining engineers in those countries where mining is carried on on a large scale can be hoped to provide sufficient evidence to establish a definite theory or theories to assist in overcoming some of the more common dangers due to subsidence.

THE RELATION OF SEISMIC DISTURBANCES IN THE PHILIPPINES TO THE GEOLOGIC STRUCTURE.

BY

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The researches of the last ten years, stimulated as they were by the tremendous cataclysms of Messina and San Francisco, have introduced entirely new principles into the study of seismic disturbances of the crust of the earth. The old centrum theory of MALLET is now generally discredited.

Beyond a doubt many seismic disturbances are due to causes other than vulcanism, and many of the worst disasters we have experienced have had nothing to do with volcanoes. That volcanoes are near by is only coincidental, or because a locus of great disturbances in the earth's crust is naturally a zone of weakness and therefore a place where molten material would seek an outlet. At the time of the Messina earthquakes, Mt. Etna, which can be seen from Messina, was comparatively quiet; these earthquakes, as is generally known, were due to an adjustment along the line of a great fault in the earth's crust which is marked by the Straits of Messina.

The work of the Italian Geological Survey has demonstrated that these disturbances are propagated along very definite lines. So thoroughly did the Italian geologists do their work that by superimposing upon a geologic and topographic map of the province of Calabria another map showing the location of cities and other works of man, with all historical data regarding earthquakes, one can see at once that: (1) certain lines are more subject to earthquakes than others; (2) points removed from these lines have suffered less or not at all; (3) the greatest disasters have occurred at intersections of these lines. These lines, which form more or less definite systems, proved to be the projections of various earth lineaments such as fault lines, joint lines, formational contact lines, and axes of mountain ranges.

The great California earthquake of April, 1906, is a striking example of this. This earthquake was due to a dislocation along the well-known San Andreas rift, and, although the waves from this disturbance were propagated to varying distances on both sides, the greatest disturbance occurred along the line of this fault.

When one can indicate a point on a map and say definitely that there the crust of the earth is unstable, seismic geology becomes of very great practical interest to humanity in general and to engineers in particular. Especially is this applicable to geologically young parts of the world like the Philippine Islands, where mountain-building is in progress and where the evidences of recent vertical movement of various portions of the island mass actually can be measured. The earthquakes of Messina, of San Francisco, and the eruption of Taal volcano are concrete examples of such disturbances. The people of Messina had been warned repeatedly, but their commercial interests were so great that they gave no heed and consequently millions of dollars worth of property and thousands of lives were lost during that disaster. This was also true of San Francisco. The reported loss of property by that catastrophe amounted to 490,000,000 dollars.

The disturbances in the region of Taal were immediately due to the volcano, but Taal volcano is located along a line of crustal weakness, and at that time a very appreciable displacement occurred along one or more lines passing through this volcano. One of these lines runs from the volcano to the coast through the town of Lemery, and the other from the volcano to the barrio of Sinisian, making with the sea a triangular strip several square kilometres in area. The whole block dropped a metre or more, so that the sea washed inland for a distance of a kilometre over the main highway along this coast. The road between Lemery and Sinisian had to be reconstructed, and considerable damage was done to buildings in the town of Lemery. Fortunately no very large structures were located along these lines or the property loss would have been much greater. We may not see in our lifetimes a recurrence of disasters either at Messina or San Francisco, but the time will surely come when there will be further displacement along these great earth-rifts. There never will be as great disasters in the Philippines, for most of the Filipinos live in basket-like houses that resist earthquakes very well; but large engineering works have been carried out, others are being planned, and large public buildings are continually being built, hence it is important to investigate this question thoroughly in the light of all the data we now possess.

The scope of the present paper is: (1) to outline the physiography and geomorphology of the Philippines; (2) to discuss the kinds and distribution of the rock formations and the major structural features of the islands; (3) in the light of these, to show the origin of each of the important seismic disturbances of the past; and (4) to draw some practical conclusions. We believe that most of the seismic disturbances in the Philippines should be attributed not to volcanoes, but to displacements along the major structure lines of the archipelago. Volcanoes are merely incidents in the growth of the archipelago, and both volcanoes and earthquakes may be traced back to lines of weakness and crustal displacements. Although many earthquakes are due entirely to volcanic phenomena, we believe we can prove that *the major earthquakes, and the majority of earthquakes in the Philippine archipelago, are not due to vulcanism.*

Until 1863 nothing was written on Philippine earthquakes.[1] Even at the present time there exist but few papers based on modern seismologic principles, and all of these have been written during the last ten years.

Manila observatory, from its foundation as a private institution in 1865, has directed its attention to earthquakes, but for many years its work was confined to segregating and publishing exact monthly observations. Its collection of monthly curves recording the hourly observations of the Bertelli microseismograph is exceedingly valuable on account of the long period of time that it covers.

The earthquake of June, 1863, which practically destroyed Manila and many of the neighbouring towns, and killed more than 400 persons, led to the nomination of a commission to investigate the architectural character of the buildings and the nature of the soil of Manila in so far as these might be a source of danger in the future. The commission was selected from the corps of military engineers and its work appears to have been limited to the establishment of several more or less successful principles and practical rules to be applied in the construction of new buildings in Manila.

Ten years later the commander of military engineers, D. Mariano Cortes y Aguillo, wrote a memoir on the same subject.[2] Notwithstanding the undoubted merit of this work as a practical guide for architects, little account was taken of it by the authorities and it was not published until after the earthquakes of 1880.

After the earthquakes of 1880 a commission composed of engineers of public works was appointed to study the ruins caused by these earthquakes, to point out the structural defects in the damaged buildings and to formulate rules for the rebuilding and repairing of the city which would be more practical than those previously prepared. This second commission, therefore, was not directly concerned with determining the causes of the earthquakes of 1880, their extent and probable epicentre. José Centeno, engineer of mines, was entrusted with this task. His memoir[3] is one of the best that has been published, from a descriptive point of view. He visited the whole territory in which these earthquakes had been most violent and hence was able to determine, with the precision possible in such cases, the meizoseismic areas of the three destructive earthquakes that took place from July 14th to 21st, 1880.

Unfortunately he did not search for the rifts and faults which would have indicated the nature of the dislocation that took place in the Eastern cordillera, and which were the causes of these earthquakes. He could not escape from the ideas then prevalent that earthquakes were related to volcanoes. If he does not actually attribute the July earthquakes to the influence of

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[1] The more or less accurate accounts of earthquakes which are scattered through the history of the Philippines are not here considered.

[2] *Los terremotos; sus efectos en las edificaciones y medios practicos para evitarlos en lo possible.*

[3] *Temblores de tierra occuridos en Julio de 1880 en la Isla de Luzon.* Madrid (1885).

Taal volcano, at least he mentions several small eruptions which were supposed to have occurred in the same year as though he wished to indicate in what direction investigations should be made should an inquiry into the origin of these earthquakes be undertaken.

A short time before this, CENTENO had been sent on a commission to the peninsula of Surigao, where several very severe earthquakes had taken place in 1879 and had left indelible impressions of their violence in the shape of numerous fissures and subsidences. In his report thereupon he assigns Mainit lake as the epicentre of the earthquakes, supposing, like many other writers, that this lake occupied an extinct volcano. Nevertheless, the great number of fissures and subsidences along the ridge of mountains, and especially in Point Bilat which is its extreme northwest extension, might have suggested rather clearly a different, tectonic cause. Some spasmodic movement, which had closer relation to the slower geological movements in this part of the island, may have occurred and been recognized by this author, for he quotes as proof that the depth of the port of Surigao had changed during the earthquakes of 1879.

Six months had scarcely elapsed after the Manila earthquakes when a long series of seismic movements, lasting from January until November, 1881, began in Nueva Vizcaya. ENRIQUE ABELLA Y CASARIEGO, engineer of mines, was commissioned to investigate the likelihood of any future seismic cataclysm in the affected province, and if such a probability existed, to report on the feasibility of removing the inhabitants to other provinces not so affected. ABELLA's work[1] is an able and complete study of the local and superficial character of the earthquakes and of their probable duration, and his predictions regarding their continuance were perfectly realized, for as he prognosticated the earthquakes ceased shortly afterwards and up to the present no other of importance has occurred. It is evident in his discussion of the origin of these earthquakes that this author also was influenced by the current volcanic theories and sought a possible connection between the disturbances in Nueva Vizcaya and Mayon volcano, which a short time before had shown signs of greater activity.

The Pangasinan earthquake of 1892 gave ABELLA the opportunity of writing another interesting memoir.[2] In this work he did not limit his studies to the earthquakes, but added many valuable notes on the geology of the provinces of Pangasinan, Union and Benguet, thus coming more into agreement with modern seismologists. Notwithstanding, in his final conclusions he places most weight on the existence of volcanic rocks and other evidences of vulcanism, both ancient and modern, as if the origin of these earthquakes could only be discovered by resorting to volcanic action either directly or indirectly.

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1 *Terremotos de Nueva Vizcaya en 1881.*

2 *Terremotos experimentados en la Isla de Luzon . . . en Pangasinan, Union y Benguet.* Manila (1893).

Several other very interesting and useful physico-geologic monographs are due to the indefatigable labours of ABELLA.[1]

In 1895 Fr. SADERRA MASÓ[2] published a book on earthquakes containing a coördinated collection of data which might serve as a basis for the future study of the earthquakes of the Philippine archipelago. Many of these data were in the archives of Manila observatory and had not been published previously, while others were scattered in histories, periodicals and other publications. The only important conclusion he draws is that the *seismic centre dangerous for Manila does not lie in the existing volcanoes south and southeast of the city, but in the eastern range of mountains and especially in the part east-northeast and northeast of Manila.*

The same writer[3] has given accounts of the more important earthquakes that have taken place in the different parts of the archipelago. During the first period he endeavoured as a rule to trace a relation between earthquakes and volcanoes. In the second period, that is, 1900 to 1912, he inclined to the more modern ideas in certain of his papers,[4] although he exaggerates the importance of volcanic manifestations when he speaks of the different epicentres as regions of greater seismic activity.

Since 1907 this investigator has written several short papers[5] on the seismicity of the different regions of the archipelago as a preparation to a more complete work like the present. In these articles he has attempted to indicate by the alignment of the different epicentres the possible existence of seismo-tectonic lines, in conformity with the recent principles of seismology.

In 1890, KOTO, professor of geology, Science College, Imperial University, Tokio, published a valuable study[6] in which he discusses the different tectonic lines and volcanic belts of the Philippines and their connection with Celebes, Borneo and the Moluccas. It is a thorough and complete study of great value and must be taken into account when drawing the tectonic lines of the Philippines.

As a general study of the geology and vulcanism of the Philippines

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[1] *Apuntes fisicos y geologicos de Nueva Vizcaya*, Madrid (1884). *Rapida descripcion fsica, geologica y minera en bosquejo de la Isla de Panay*, Manila (1890).
El Mayon o Volcan de Albay, Madrid (1885). *Emanaciones volcanicas subordinadas al Malinao*, Madrid (1885).
El Monte Maquiling y sus actuales emanaciones volcanicas, Madrid (1885).
La Isla Biliran y sus azufrales, Madrid (1885).

[2] *La Seismologia en Filipinas*, Manila (1895).

[3] Monthly bulletins of the Manila observatory, 1897, and from 1900 to 1912.

[4] *Report on the seismic and volcanic centres of the Philippine Archipelago*, Manila (1904); *Volcanoes and seismic centres of the Philippine Archipelago*, Manila (1904), as part of the census of the Philippine Islands.

[5] *The earthquake of Ambos Camarines;* Bull. P.I. Weather Bur. (April 19th, 1907), p. 172; *The earthquakes of the Batanes Islands and southern Formosa*, ibid. (1909); *The seismic centres of northern Luzon*, ibid. (1909); *Submarine seismic centres near the coasts of northern Luzon*, ibid. (1909); *Seismic centres near Western Mindanao and Jolo*, ibid. (1910); *Seismo-tectonic lines in southern Luzon*, ibid. (1911).

[6] *On the geologic structure of the Malayan Archipelago;* Journ. Coll. Sc., Imp. Univ., Tokyo (1893), Vol. V, Pt. II, p. 2

BECKER's report[1] is the most complete work that has appeared. It contains an excellent résumé and criticism of all writings on the subject that had been published up to that date.

The names of several Austrian, German and French geologists and explorers to whom we owe the first geological data of the Philippines should also be mentioned. The principal ones are VON RICHTHOFEN, CARL SEMPER, OEBBECKE, K. MARTIN, JAGOR, ROTH, R. VON DRASCHE, and J. MONTANO. Likewise attention is called to the works of the eminent French seismologist MONTESSUS DE BALLORE, who published many articles on Philippine earthquakes during the years 1895 to 1901. In one of his books[2] he gives a summary of these articles on the earthquakes of the Philippines. This author must be considered as the first to apply to this archipelago the principles of modern seismology, by referring its earthquakes not so much to imaginary volcanic agencies, as previous authors had done, as to the principal geological accidents, in other words, to tectonic lines. Hence the work referred to above must in justice be reckoned the first and most important contribution to the study of Philippine seismology.

SUMMARY OF THE PHYSIOGRAPHY OF THE PHILIPPINE ISLANDS.

To present a clear idea of the underlying causes of seismic disturbances in the Philippine Islands, some general statements are necessary. The Philippine Islands form a link in the chain of outliers of the old Australasian continent. According to the "horst" theory of the formation of continents and ocean basins, the Philippine Islands lie at the very edge of the Asiatic horst. In June, 1912, the German survey ship *Planet* sounded to a depth of 9,780 metres about 60 kilometres off the northeast coast of Mindanao.[3] Soundings to the westward of the Philippines have not yet located any such tremendous depths.

The Philippine Islands may, then, be regarded as being at the edge of the continental platform. This platform was raised above sea-level and complexly folded during what is known as the "Miocene revolution," which extended from New Hebrides through the Philippines northward to Japan; westward across Burma, India, Persia and Egypt; northward to the Vienna basin; and westward even to the Pyrenees. Following this crumpling of the crust, a gradual tilting of the Philippine block toward the east seems to be going on at the present time. This is indicated by raised coral reefs on the western coast of northern Luzon and the western coast of Palawan, raised deltas and beaches on the western coast of Zamboanga peninsula, and drowned river basins which are known to occur on the eastern coast of Luzon, and are thought with less certainty to occur at other points in the archipelago.

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[1] *Report on the geology of the Philippine Islands*, 21st Annual Rep. U.S. Geol. Surv., Washington (1901).

[2] *Les tremblements de terre*, Paris (1906).

[3] Ann. Geog. No. 120, Nov. (1912).

VON RICHTHOFEN,[1] long ago noticed a peculiarity of the Philippine archipelago and the Japanese, Riukiu, Kurile and Aleutian chains of islands: they constitute a series of arcs with their convex sides turned toward the Pacific. One of these arcs is well marked in the Philippines by the tectonic line passing through southeastern Luzon, Samar and the Eastern cordillera of Mindanao. Northern Luzon does not conform very well to this arc, but there may have been a fault and offset at the narrow portion of the Island of Luzon at the northern end of Tayabas peninsula.

Besides this dominant curved line, and those parallel to it in the eastern part of the archipelago, there are in the Philippines several other distinct tectonic lines, as shown in Plate I. One of these is the Palawan line, another is the Sulu archipelago line, others are the parallel lines passing northeast and southwest through Panay, Negros, and Cebu, all trending northeast and southwest. Masbate seems to be the "keystone" of the Philippine structure. The eastern prong of this island conforms closely with the outermost arc of the archipelago, while the western prong conforms with one of the northeast-southwest lines passing through eastern Panay.

The physiography of the islands may now be taken up in detail. In the northern part, on the Island of Luzon, there is on the east side a cluster of volcanoes containing Bulusan, Mayon, Isarog, and Iriga; west of this is the narrow Albay plain, then a belt of Tertiary sediments and farther west a trough occupied by Ragay gulf. The anticlinal of folded Tertiary sediments marked by Tayabas peninsula lies west of this and is succeeded in the same direction by the volcanic group consisting of Banahao, Cristobal, Arayat; the central plain of Luzon, partly a tuff plain and partly alluvial; and, farthest to the west, the line of extinct volcanoes marked by the Zambales cordillera. The zonal arrangement is not so marked in northern Luzon. Recent volcanoes are few, Kawa in Isabela province being the only one known in that section.

This same general zonal arrangement of formations exists in the Visayas, but the evidence of vulcanism is not so marked as in Luzon. The islands are characterized by anticlines and the narrow straits by synclines.

This is likewise true of Mindanao. Along the eastern coast there are Recent and Tertiary sediments which flank a core of igneous rocks immediately to the west and dip eastward toward the "fossa," or trough, just east of Mindanao. West of this in succeeding order lie the great Agusan trough, an interrupted volcanic chain marked by such prominent points as Matutan and Apo, the great alluvial flat occupied by the Rio Grande de Mindanao, the regular zone of volcanic peaks marked by Malindang and the old craters south of Lake Lanao and those in the unexplored region south of the Rio Grande, a belt of folded Tertiary sediments, the synclinals marked by Sibuguey bay, and last the anticlinal represented by Zamboanga peninsula.

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[1] *Geomorphologische Studien aus Ostasien;* Sitzungsber. d. k. pr. Akad. d. Wiss. z. Berlin.

Cross folding, probably accompanied by faulting, has broken up the Philippine block in such a way as to produce numberless smaller islands in line with the main tectonic lines that extend through the larger islands.

Types of mountains.—Folded and volcanic mountains are the two dominant types in the Philippines; the block type is suspected to occur in some places where as yet insufficient data has been obtained to decide this point. It might seem at first sight that the majority of the mountains in the Philippines are volcanic, but these are merely superimposed upon the folded mountains or are located along other lines of weakness. While there are a few active volcanoes in the Philippines, most of them are extinct or dormant, as shown by the many worn down volcanic stocks which preserve varying degrees their former outlines.[1]

The principal folded mountains are the Central cordillera of Luzon, the Eastern cordillera, which has its southern continuation in Tayabas province, and the cordilleras of Cebu, Leyte, eastern Mindanao, and various other parts of the islands.

Block mountains are rare in the Philippine Islands, but at Bamban on the main line of the Manila and Dagupan railway in Luzon there are some hills which are due to the Tertiary sediments having been tilted up like blocks. From the railroad the tilted beds present a bold escarpment to the east that is undoubtedly due to a fault, but they dip gently to the southwest.

On the Island of Panay the secondary ranges—those flanking the Central cordillera—are tilted blocks of Tertiary sediments. The strike of these secondary ranges conforms exactly to the strike of the sediments and their eastern slopes correspond invariably to the dip of the formations. The slopes on the sides where the upturned edges of the sandstone and the shale beds can be seen are precipitous. Displacements along the bedding planes of these formations are frequent and have undoubtedly given rise to many local quakes.

Kinds of rocks.—Before discussing the tectonic features of the islands the distribution of the various classes of rocks must be considered. These include: (*a*) deep-seated igneous, (*b*) extrusives, (*c*) intrusives, (*d*) Tertiary and older sediments, (*e*) metamorphic rocks, (*f*) recent alluvial and pyroclastic deposits.

(*a*) The deep-seated igneous rocks are diorite, gabbro, pyroxenite, peridotite, and syenite. These rocks have all been fully described.[2] Their distribution is the principal thing of importance in this discussion. The deep-seated rocks are naturally not very widely distributed on the surface, and are found usually out in the cañons of the central ranges. They are particularly abundant in northern Luzon, throughout the Central cordillera.

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[1] These various volcanoes have been taken up in other articles in more or less detail. The centres of volcanic activity at the present time are Taal volcano in Batangas province, Mt. Mayon in Albay province, Luzon; Mt. Canlaon in Negros; and the Island of Camiguin just north of Misamis, Mindanao. All of these volcanoes have been in eruption within the last ten years, and to them can be attributed many of the minor seismic disturbances to which the archipelago has been subjected.

[2] IDDINGS, J. P., Phil. Journ. Sci., Sec. A. (1910), Vol. V, p. 155.

in the Island of Palawan, the Western cordillera of Panay, the Central cordilleras of Cebu and Leyte, the Eastern cordillera of Mindanao, on the Island of Masbate, in fact, wherever the topography has had sufficient relief for the streams to cut through the overlying, younger formations.

(b) In all parts of the islands there is a large amount of extrusive material, which forms a mantle over the deeper-lying formations. Naturally these extrusives are found around the volcanic areas. They are very pronounced in the Zambales ranges of southwestern Luzon and in various parts of the Central cordillera lying above the old igneous rocks and the Tertiary sediments. Great patches of andesite in the Central cordillera of Luzon mark probably early Tertiary volcanoes. In the Zambales mountains there is a great development of andesite marking probably a still later period of volcanic activity. Basalt occurs on Mt. Arayat, which rises isolated out of the central plain of Luzon, and around Taal volcano and on the Bataan peninsula there is a considerable amount of basalt. Extrusives are particularly well developed in the southeastern volcanic cluster of southeastern Luzon, comprising the well-known peaks of Bulusan, Mayon, Isarog, etc. They overlie much of Masbate, particularly in the central portion. They also occur in western Panay, a portion of Cebu (these may be intrusive), most of northern Negros, central Leyte, and notably in Mindanao, where a broad belt of extrusives extends north and south through the Apo and Matutan ranges. There is a great patch of basaltic material around Lake Lanao, and a great volcanic mass of which Mt. Malindang is the centre. These extrusives also cover almost the entire islands of Basilan and Jolo and the lesser islands of the Sulu archipelago.

As yet extrusives are known only in the north of Palawan. The principal mountain mass of Mindoro, Mt. Halcon, is largely andesitic.

One general conclusion can be drawn from the distribution of the extrusives in the Philippine Islands, namely, that all the recent volcanic materials, as far as known, are basaltic, and the older stocks are without exception andesitic.

(c) Small and large intrusions of diorite, granite and basalt are innumerable throughout the islands. Those in the Central cordillera of Luzon seem to be generally diorite. They cut both the Tertiary sediments and the overlying extrusives. In the province of Ambos Camarines in southeastern Luzon granitic intrusions cut the diorite and possibly also the sediments. In the Sulu archipelago we have found a number of small basaltic intrusions cutting some of the recent sediments. Owing to the lack of an accurate base map of the Philippine Islands and to the fact that our work has been largely of a reconnaissance nature, these intrusions have not been mapped in detail or with sufficient accuracy for us to state whether or not they follow any general system of jointing or earth lineaments.

(d) Flanking all the cordilleras on both slopes there is a greater or less development of sandstones, shales and limestones which have been arched upward in the general Miocene uplift referred to above, with some minor crumpling at various points. The folding in the northern part of Luzon has apparently been a gradual and gentle uplift of the strata. In Tayabas peninsula the strata have been so intensely compressed that schists have resulted. These schists have been considered by some to be pre-Tertiary, but there seems to be no good reason for not referring them, in part at least, to the Tertiary. The central portion of Mindanao consists of gently folded sediments. The major axis of folding in the Philippines is in general north and south; along the outside arc of the islands it is northwest and southeast and on the inside, northeast and southwest, but in central Mindanao, in the Cotabato valley, the axis of folding is more nearly east and west.

(*e*) Metamorphic rocks occur in various parts of the islands. In the province of Ilocos Norte there is a considerable development of schist, and in Ambos Camarines schist and gneiss are developed in considerable amounts along the border of the granite intrusion referred to above. Schists have been found at one locality in the Central cordillera of Cebu, at various points in Palawan, in Zamboanga peninsula in the province of Bukidnon, Mindanao, on Surigao peninsula just east of the Gulf of Davao, at one point on Tayabas peninsula, and on Caramoan peninsula in southeastern Luzon.

(*f*) Recent alluvium carried from the mountains and deposited upon coral shelves forms more or less coastal plain around all of the islands. Most of these plains are negligible, but some of the intermontane plains are very important. The northern three-fourths of the central plain of Luzon is largely alluvial. The Albay plain is largely alluvial as is the case in the great valleys of the Cagayan, Agusan and Cotabato rivers. The central plain of Panay also shows a very considerable accumulation of detrital material.

Around Manila we have, in addition, a great area of pyroclastic material which is cut through by Pasig river. This is known from well logs and river sections to be at least 100 metres thick.

TYPES OF SEISMIC DISTURBANCES.

Modern seismology, in rejecting every agent and force external to our planet as causes of earthquakes, reduces the classes of shocks to the following three types: volcanic, tectonic, and rockfall.

Many examples of these three types are to be found in the seismological records of the Philippine Weather Bureau, and a few of the more characteristic will briefly be mentioned.

To the *volcanic type* belong all those earthquakes that are intimately connected with volcanic eruptions caused by explosions or sudden outbursts of steam. These volcanic earthquakes, contrary to popular belief and to the ideas generally held for many centuries by scientists, are in reality of but slight importance and occur only in certain restricted districts.

The recent eruption of Taal volcano, January 27th to February 8th, 1911, produced a very typical series of these earthquakes. On the night of January 27th, severe earthquakes occurred on Luzon and in adjacent regions, while at the same time or very shortly afterwards it was noticed that the principal crater of the volcano increased in activity. This activity, as well as the frequency and intensity of the shocks, continued to increase during the 28th and 29th, until at approximately 2.26 a.m. of the 30th the greatest and most destructive eruption recorded in the history of the volcano occurred. After this paroxysm the volcano soon relapsed into its normal state, although earthquakes continued to be very frequent during the three following days, January 31st and February 1st and 2nd, thus indicating that energy was still accumulating in the interior of the volcano. During the eruptive period, January 27th to February 7th, 995 shocks were recorded in Manila observatory, all of them between I and V of the Rossi-Forel scale. Some of the principal shocks were perceptible at a radius of from 120 to 200 kilometres. The meizoseismic area of the earthquakes was an elongated zone which took in not only the volcano itself, but also the south-southwestern part of Laguna de Bay and the bordering territory as far as the sea, some 20 kilometres away (see page 824).

The decrease of perceptible intensity of the seismic action outside the epicentral area was, according to many comparisons made on the spot, one degree of the Rossi-Forel scale for every 15 kilometres. The same result was also deduced from the fact that the maximum intensities of several of the earthquakes as felt in Manila, 63 kilometres away, were from IV to V of the scale, while in the epicentre, judging from the effects upon the ground and upon buildings, they were from VIII to IX. These same earthquakes, which had an intensity VIII to IX in the epicentre and IV to V at a distance of 63 kilometres were also felt at Taihoku (Formosa) about 1,000 kilometres away.

The reports of previous eruptions of Taal also mention numerous volcanic earthquakes, which no doubt possessed the same characteristics as those that occurred recently. A curious fact is noted in these reports that while in the recent eruption the meizoseismic area extended 20 kilometres to the south-southwest, in the previous eruptions it extended to the northnortheast for about 30 kilometres, as far as Laguna de Bay. From this it is easy to recognize the direction of the rift on which the volcano originated.

In 1871 a series of volcanic earthquakes occurred on the volcanic island of Camiguin, north of Mindanao. These earthquakes culminated in the opening of a small crater whose activity lasted four or five years. They were first felt in February and increased in intensity and frequency until the morning of April 30th, when the volcano exploded and the earthquakes suddenly ceased. Most of these shocks were perceptible on the island only, although many were also heavily felt on the neighbouring coasts of northern Mindanao and southern Bohol, while only four or five, whose intensities in the epicentre were between VII and X, were noticed at a distance of 250 kilometres.

The following table gives some idea of the number and intensity of the shocks preceding the eruption of Camiguin.

TABLE I.—EARTHQUAKES REGISTERED AT MANILA.

Date.	Earthquakes.	Remarks.
February 16.	Two slight earthquakes.	
February 17.	Frequent shocks during day and night.	
February 18.	Frequent shocks during day and night.	One of intensity VIII.
February 19.	Frequent shocks during day and night.	One of intensity VII.
February 20.	Frequent shocks during day and night.	
February 21.	Frequent shocks during day and night.	One of intensity IX.
February 22.	Frequent shocks during day and night.	One of intensity VIII.
February 23–28.	Frequent shocks during day and night.	
March 1–3.	Frequent shocks during day and night.	
March 4.	Frequent shocks during day and night.	One of intensity VI.
March 5–7.	Less frequent, not more than 10 per day.	
March 8.	Less frequent, not more than 10 per day.	Two of intensity VI.
March 9.	Less frequent, not more than 10 per day.	
March 10.	Less frequent, not more than 10 per day.	Two of intensity VI.
March 11–13.	Less frequent, not more than 10 per day.	
March 14–17.	Less frequent, 4 or 5 per day.	
March 18–19.	More frequent and violent than during preceding days.	
March 20–31.	Less frequent, not exceeding 6 per day.	
April 1–29.	Frequent during the entire month; number never less than 6 to 10 per day.	
April 30.	At 7 a.m., with a terrific detonation and emitting a cloud of vapor, rocks, and ashes, a volcano burst on the north-northeastern end of the island, only a few metres from the shore. After this explosion, semisolid lava continued to rise quietly for about three years, building up a cone approximately 440 metres high. The ashes of the first explosion were carried to distances of 200 kilometres. Within a radius of 2 to 3 kilometres from the new crater the destruction was complete. The earthquake ceased almost completely a few days after the eruption. There was no town nearer to the volcano, and in the only one destroyed by it the people had deserted their homes long before, some having left for other islands as early as the end of February.	

The *tectonic type* of earthquakes is caused by sudden relief of strains due to contractions and foldings in the crust of the earth; when these pass the limit of equilibrium and the modulus of elasticity of the crust they give rise to rents and fractures and other sudden movements of more or less severity, depending on the degree of the accumulated stress. This type comprises the greater number of earthquakes felt in all parts of the world and in particular all those of greater intensity and extent. To it belong practically all the great Philippine earthquakes enumerated by Fr. SADERRA MASO,[1] which occurred in eastern Mindanao, in the valley of the Agusan, and on the

[1] *Catalogue of violent and destructive earthquakes in the Philippines;* Bull. P. I. Weather Bur. (1910).

Pacific coast, regions which appear to be closely related to "the Philippine deep," the great submarine trough of 9,780 metres already referred to. Further on we shall discuss some of the tectonic earthquakes of greater importance.

The *rockfall type* embraces the earthquakes of small extent, which, having their focus or seat of origin at a slight depth, are brought about by the fall of rock in caves and underground passages, and in certain cases by the settling of superficial rock-masses displaced by tectonic seismic motions. It appears that this is the predominant type of shocks felt in several non-volcanic regions of the Philippines, but earthquakes of this type are very often extremely difficult to recognize on account of the distance between the seismic stations and the large extent of the uninhabited mountainous and forested districts in which they occur, so that it is impossible to fix the limits of the area where many of the earthquakes are perceptible. The earthquakes of 1881 in Nueva Vizcaya are unimportant examples of this class. From January to October of that year there was a continuous series of earthquakes, the maximum intensity and frequency of which occurred in September. To get an idea of this seismic period, the well-known catalogue of the missionary XAVERT should be consulted. This catalogue includes 63 days between January and October, and contains the record of 196 earthquakes with the times at which they occurred. Phrases such as "almost continuous," "many more," "the whole day," "the whole night" appear 25 times in the list, thus indicating that the smaller earthquakes were not counted.

ABELLA, who examined the effects of these earthquakes in the field, found that the meizoseismic area was very small and that its centre coincided with the town of Bambang. The great majority of the shocks were only perceptible within an area of 60 kilometres, so that only five of intensity VII to IX exerted any influence beyond the province. Much of the data supplied by ABELLA fully confirms his statement, which is further strengthened by an examination of the records of the hourly observations of the Bertelli microseismoscope or tromometer made in Manila observatory.

With the catalogue of XAVERT before us, these observations have been examined again and we have not been able to find any movement which could coincide with the Nueva Vizcaya earthquakes, other than those corresponding to the larger shocks mentioned above and three or four other doubtful ones. The experience of 17 years shows us that this tromometer, still in use at the observatory, indicates perfectly all earthquakes of any great extent and of intensity III or greater whose epicentres lie within a radius of 200 kilometres from Manila.

ABELLA concluded from these facts that the seat of origin of the earthquakes must be very superficial and of small extent, and hence the conclusion that there was little likelihood of any greater ones happening in the future was fully verified. Such earthquakes could not in any way be classed as tectonic and hence the author attributed them to volcanic influences, suggesting that the subterranean forces which at that time had given greater activity to Mayon volcano might possibly have extended toward the northwest and affected the province of Neuva Vizcaya, some 400 kilometres from Mayon. After the examination of ABELLA's report it seems evident that the earthquakes of Nueva Vizcaya belong to the rockfall type; and this opinion is strengthened by a consideration of the topography of the province. The whole province is an elevated mountainous region of the nature of a plateau, separated from the plains of Luzon to the south by a line of steep cliffs while on the west it is bounded by a series of peaks whose precipitous western slopes rise abruptly from the deep cañon of Agno river.

Besides the earthquakes of Nueva Vizcaya, many of those that take place in Mountain province, which comprises the former districts of Benguet, Bontoc and Lepanto, possibly are of the same character. In many parts of this region, particularly in the western part where coraliferous limestone predominates, recent fractures and subsidences are met at every step. The same might be said of other parts of the archipelago having a similar geological structure.

DISTRIBUTION OF SEISMIC DISTURBANCES.

In the Philippines as in all other seismic regions of the globe, most earthquakes originate along determined lines which constitute special features of the topography of the archipelago.

If we add to the *Catalogue of violent and destructive earthquakes in the Philippines 1599-1909*, cited above the earthquakes which have occurred since that time, the distribution of tectonic epicentres[1] is as given on the map (Plate I).

The region which has suffered most from violent earthquakes during the past 50 years is without doubt eastern Mindanao, and particularly Agusan valley. We have no seismic data concerning this region previous to 1889, doubtless owing to the undeveloped state of that part of the archipelago and to the consequent lack of communication with the outside world. The great deep-sea trough which exists along the east coast of this part of the island indicates that many earthquakes must have occurred there since it first began to form. The same may be said of the coasts of the island of Samar which also are exposed to the influence of the same "deep," and hence are as unstable as the eastern coast of Mindanao. The principal epicentre of Samar is near the northeast coast.

In the island of Mindanao there exist the following seismic regions: the Gulf of Davao and the districts of Cotabato between Apo volcano and Illana bay, the coast along Illana bay and the district of Lanao, and the extreme western part of the island near Zamboanga. The island of Basilan and the archipelago of Jolo are also in a region of great seismicity, although the epicentres seem to lie in the neighbouring seas. The district of Dapitan in the northwest is affected by a submarine epicentre situated between Dapitan and southern Negros. All the central part of

[1] The word "epicentre" is used in the broad sense as the region where important earthquakes originate.

northern Mindanao comprised within the district of Misamis appears to be a region of much greater stability, but the neighbouring island of Camiguin has suffered much at different times from volcanic earthquakes. The Visayan islands, in addition to what has already been mentioned of Samar, have two regions of great seismicity, Panay and Leyte. An epicentre lies in Iloilo straits between Panay and Negros, while within the island of Panay at a distance of about 30 kilometres from the southeast coast there is another more important one where very violent earthquakes, apparently of the rock-fall type, originate. In Leyte there are two volcanic epicentres, in the north and northeast, and there is probably a rockfall epicentre to the west close to the Camotes islands.

The islands of Cebu and Bohol, and perhaps also Oriental Negros, may be considered as stable. However, Oriental Negros was very probably in the past the scene of many volcanic earthquakes, though the data we possess are very deficient. Post-Pliocene volcanic formations do not occur in Cebu.

The principal seismic regions of southeastern Luzon and adjacent region are those of Camarines, Albay and Masbate, with three principal and well defined epicentres: the first along the central depression of Ambos Camarines, the second to the north of San Bernardino strait, and the third in the island of Masbate or near its northern and southern coasts. Between Sorsogon bay and the Gulf of Albay there is also an epicentre of small extent and intensity.

The southern part of Luzon constitutes the second seismic region of greater importance in the archipelago. Four epicentres may be distinguished in it; one in the east, near the coast, which appears to stretch from the north of the Bay of Lamon southward in the sea between Mindoro and Marinduque; a second between Mindoro and Luzon; a third in the China sea along the coasts of Cavite and Zambales; and the fourth, which may be called the Manila epicentre, is situated in the Eastern cordillera and its spurs, between Laguna de Bay and the Gulf of Baler. The volcanic epicentres of Taal and other volcanoes are not reckoned.

Northern Luzon from parallel 16° northward contains four extensive seismic regions. That of Pangasinan, the long axis of which appears to cross the island approximately from east to west from the Bay of Casiguran to Lingayen gulf, following the limit of the great central plain of the island. The Nueva Vizcaya epicentre may be considered as belonging to this central seismic region. The second region comprises the various epicentres of Ilocos Sur and Norte, some of them in the sea close to the coast, others probably at the extreme east of the plain or coastal belt which borders these provinces. The third region, which is an important one, is situated along the central mountain chain of Mountain province and extends as far as the Babuyanes islands. Within the confines of the extensive Cagayan valley there are very important tectonic lines, but they have not, since 1645, given rise to any very great earthquake. However, there are frequent earthquakes of slight extent and intensity, those occurring in the north being probably of volcanic origin, while those in the south are due to epicentres whose influence seems to be decreasing.

In the extreme north of the archipelago and outside the limits of Luzon there are at least two epicentres close to meridian 122° east, one stretching from the volcanic island of Camiguin to the northeast coast of Luzon and the other not far from the Batanes islands.

In Luzon, therefore, no province is free from the effects of earthquakes, for although it is true that in some of them, such as Tarlac, Union, Isabela, Cavite and Pampanga, no epicentre seems to exist, yet they are affected by the movements which originate in other provinces.

Seismotectonic lines.—Plate I gives the location of the principal seismic areas (ellipses) of the islands, (the stars indicating the principal epicentres in these areas) and the general direction of certain principal mountain chains.

Each figure includes one or more epicentres and shows the general shape and extent of the meizoseismic areas corresponding to the greatest earthquakes which have occurred within the region limited by the same. The figures 3, 5, 7, 8, 9, 10 and 23 bear a heavy line to indicate that the earthquakes originating near the same place have been too numerous to be specified. Twenty-five different areas are recorded and of these five (12, 13, 15, 17 and 18 on the map) are undoubtedly due in large part to rockfall and volcanic activity, the other 20, in our opinion, being due to tectonic causes. This is probably quite contrary to the general belief regarding earthquakes in the Philippines. The tectonic areas are 1 to 11, 14, 16, and 19 to 26. *The areas of greatest seismicity are 2, 3, 4 and 21, where at the present time there is no known volcanic activity and where probably there has been none since the end of the Tertiary period.*

Following the methods of other students of seismology we have connected the various epicentres shown on the map by lines and have also added a few more of the latter where no epicentres are indicated. There is a remarkable coincidence between the lines and the principal lineaments in the Philippines. These various lines are denoted A-A, B-B, etc., on Pl te I so that they can be easily referred to.

Line AA, which is drawn through many epicentres, passes through the northwest corner of the province of Ilocos Norte, follows approximately the coast west of the city of Vigan, and then cuts across the northwest portion of Pangasinan peninsula. It is impossible definitely to state whether this line marks a fault line which lies along the coast or is due to a contact between the recent sediments and the older rocks, which here lie close to the coast, but we are of the opinion from geological studies in the province of Ilocos Norte that it is the latter condition.

There is a very small development of coastal plain in this region and also of rocks of doubtful, possibly Jurassic age against which these very recent sediments abut. There is also a considerable development of raised beaches and raised coral reefs along this coast, making it plain that elevation has taken place along this line recently. Whether this elevation has been accompanied by differential movement we are unable to say.

There are no evidences of recent volcanic activity in any part of the region, but granites, schists and some very old andesite are present.

Line BB connects epicentres of northern and southern Luzon, cuts through Dalupiri, the westernmost of the Babuyanes islands, then follows very closely the Central cordillera southward through the Agno valley thence eastward of the Zambales range, and on through the island of Mindoro, where it cuts the latter west of the great volcanic stock of which Mt. Halcon is the principal peak. There is no information with regard to the rocks on Dalupiri. However, the rocks of the Central cordillera in Luzon have a core of igneous rock, chiefly diorite, which is flanked by Tertiary sediments that have been arched upward. At various points along the crest of this arch extrusive rocks can be found in abundance. No volcanic activity now manifests itself in that region, but it is a region of hot and of salt springs. It is a line along which there was considerable extrusion of igneous rocks in the past, but there is no evidence of this now, therefore seismic disturbances which take place along this line at the present time are due to displacement along a line of weakness rather than to any volcanic activity. *It is significant that all of these points where either past or present volcanic activity is manifested should be found to lie along more or less definite, and in many cases, straight lines.*

Line CC is the next prominent line which runs at right angles to the B line and lies either on or very close to four epicentres. At the upper end of the central plain of Luzon the mountains rise rather abruptly and present a front which has a general east and west direction. It is very possible that this line represents a fault line where the central plain represents the downthrow side. That area has not been studied in detail, but it appears as if there is a definite break along that line. In a more arid region one would expect to find definite escarpments facing to the southward, but in a region of high rainfall like the Philippine Islands these escarpments would soon be obliterated so that their existence can only be inferred.[1]

Line DD is a very prominent one running along the archipelago close to the 122nd meridian. It connects the epicentres of the Batanes islands, Cagayan valley, Casiguran bay, that east of southern Luzon and Mindoro, and that west of Mindanao. The northernmost part of the line, outside of Luzon, follows very closely the Batanes and Babuyanes volcanic chain, studied by H. G. FERGUSON[2] and represented by the cones Yami, Mabudis, Iraya, Balintang Rocks, Babuyan Claro, Camiguing, and Didicas. Within Luzon it passes not far west of Caua volcano, southward along the structural Cagayan valley, following the trend of the Eastern cordillera until this turns toward the southwest, or rather when it seems to be interrupted by the gap forming Casiguran and Baler bays. From the latter bay

[1] HERMANN, RAF., Phil. Jour. Sci., Sec. A (1911), Vol. VI, p. 331.
[2] Manuscript report.

it follows the eastern coast of Luzon and passes to Mindoro sea through the volcanic region of Tayabas province. Farther south it passes fairly close to Tablas island, which is oriented in this direction, thence to the west coast of Panay, ending finally between Basilan and Jolo. The general topographic features suggest that this is a very characteristic tectonic or structural line, though definite geological reconnaissances are wanting to confirm such an hypothesis.

Line EE passes through many epicentres. It lies just west of the epicentre near Bayombong, Nueva Vizcaya, and passes through some near the east coast of Luzon and Lamon bay and at the southeast corner of Leyte and connects with the epicentres located around the northern point of Surigao peninsula. This line conforms to the Central cordillera of Leyte, to the coast range of Masbate and the synclinal marked by Ragay gulf, but we are not certain that it conforms to any particular lineament in Luzon for it passes through country about which there is little geological information. There are closely folded sediments whose strike is N.W.-S.E. in the eastern portion of Masbate, and ADAMS[1] has visited the island of Leyte and mapped the cordillera, showing its axis to be approximately along this line.

Line HH, which has been called "The Taal Volcano line,"[2] starts from the northwestern part of Mindoro and in a nearly northeast direction crosses Taal volcano, the western portion of Laguna de Bay, extending into the Eastern cordillera east of Manila, and thence runs toward Baler and Casiguran bays. The southern portion of this important line from Mindoro strait to Laguna de Bay has been accurately identified;[3] while the probability of its continuation across the Eastern cordillera toward the Pacific has been demonstrated by SADERRA MASÓ.[4] This line passes through the epicentre of Manila, located in the Eastern cordillera, east and east-northeast of this city.

Line FF is located along the epicentres west of the Zambales coast and another located just north of Mindoro. It intersects several of the lines already mentioned near Cape Santiago in southern Luzon. It does not follow any well marked rift, but follows approximately the trend of the Bataan coast of Luzon.

Line GG begins north of Mindoro, passes along the western coast of Cavite, follows the western border of the central plain, across Pangasinan province, and thence along the axis of the coastal ranges of Union province. A displacement along this line would account for the earthquakes described in Charts VI, X, XIII, XV, XVI, XIX, XXIII[5] with their epicentres apparently around or in the northern part of Manila bay. It is a contact line

[1] Phil. Jour. Sci., Sec. A (1909), Vol. IV, p. 339.

[2] Fr. SADERRA Y MASÓ, Bult. P. I. Weather Bur. (1911), Vol. IV.

[3] W. E. PRATT, *The eruption of Taal Volcano;* Phil. Jour. Sci., Sec. A (1909), Vol. VI, p. 263.

[4] Bull. P. I. Weather Bur. (1911), Vol. II.

[5] *La Seismologia en Filipinas.*

between andesite and the alluvium of the central plain, and between Tertiary sedimentaries and igneous rocks in Union province.

Line JJ does not pass through any very important epicentre, but cuts through San Bernardino channel and follows the east coast of Panay, passing through the centre of the island of Guimaras. We have drawn a line along these points because there is a contact on the island of Guimaras between Recent sediments to the west and the igneous rocks found on the east. It is our belief that the earthquakes which have been experienced on the eastern coast of the island of Panay are due to displacements along this contact. The continuation of this line also might explain the trend of this same coast of Panay.

Line II cuts through the Dapitan epicentre and three others which lie close to it. It also follows approximately the long axis of the island of Cebu and of Zamboanga peninsula, but it is drawn to the west of the axis of Zamboanga peninsula because some earthquakes are believed to have originated from displacements along the west coast of this peninsula.

Line LL passes through an epicentre at the southern point of the island of Samar, through another near the end of the southeastern prong of Leyte, through the island of Camiguin where there is an active volcano, and then follows the trend of Misamis bay in Mindanao and finally passes close to an epicentre situated in the middle of the sea between Cotabato and Zamboanga. Formations at the lower end of Samar and Leyte are but little known, but there is a dormant volcano on the island of Camiguin and where the line crosses Mindanao there is more or less basalt. Misamis bay probably marks some sort of a rift in the formations.

Line MM passes through many epicentres in the island of Mindanao. It intersects the L line east of Dumanquilas bay, passes through an epicentre west of Pollok, then follows very closely the trend of Cotabato river to the point where the river turns northward, and thence through an epicentre in the sea east of the southeastern point of Mindanao. The agreement between this line and the lower course of Cotabato river, which is probably more than a coincidence, is to be noted.

Line NN connects important epicentres in Camarines, Nueva Vizcaya, Samar, Leyte and the northeast coast of Mindanao. It passes through the narrow strait of San Juanico separating Samar from Leyte, and along the Camarines valley northwestward, striking the eastern coast of Luzon south of Casiguran bay. In the Albay valley it follows the contact line of the northern volcanic cluster along which the most violent earthquakes of the Camarines seem to originate, probably owing to differential movement between the sedimentaries and the volcanic area or possibly in the sedimentaries alone. Farther in the interior of Luzon this line would pass very close to the Nueva Vizcaya epicentre, but this epicentre is considered as of the rockfall type.

Line N_1N_1 is a secondary one which would pass through the Sorsogon and north Samar epicentres. This line nearly coincides with the contact between the sedimentaries and extrusives west of Sorsogon; eastward it follows the tuffs and agglomerates of the lowland extending from Sorsogon to Gubat. In the St. Bernardino straits and in the north of Samar it nearly conforms to an indentation of the "Philippine trough" along which are located some epicentres affecting Catanduanes, Albay and northern Samar.

Line OO begins close to the epicentre at the southern point of Samar, continues south to the island of Dinagat through the epicentre at the northern point of Surigao peninsula, then approximately conforming to the Matutan range it passes through the epicentre near Mt. Apo, and finally through the island of Sarangani. We do not know the composition of the rocks of the central part of the island of Dinagat, but on Surigao peninsula crystalline schists flanked by Tertiary and Recent sediments have been noted. In the neighbourhood of Lake Mainit the rocks are volcanic, although just to the east of this body of water is a belt of metamorphics. In the Matutan range the rocks are largely extrusives of more or less recent date.

Line PP passes through three epicentres and along very important structural lines in the archipelago. Beginning at the north, it passes between Cantanduanes and Luzon islands, through Batan island and south through an epicentre located near the southern end of Leyte. From here it extends through another epicentre in Butuan bay, thence follows closely the structural line of the Agusan valley in Mindanao and finally emerges from Mindanao near the town of Mati. Very little is known about the geology of the parts of the archipelago traversed by this line. In the island of Batan the rocks are largely sedimentary but their strikes do not coincide at all with this line.

The Agusan valley in Mindanao is very clearly a structural valley. What the condition of the rocks is, with depth, we do not know the alluvial filling in the Agusan trough conceals everything. This line is one of the most important in the archipelago, and has been described in previous articles.[1] In the first of these Fr. SADERRA MASO says:

"We call this line the line of the Agusan River Valley because *the portion of it which lies within the said valley has been the seat of the greatest number of violent earthquakes which have occurred during the last fifty years.* The first seismic district of importance on this line comprises the large gulf of Davao, 120 kilometers long and 50 to 70 kilometers wide. The average depth of this basin is 800 meters, increasing, however, towards the southeast in such manner as to exceed 1,650 metres west of Cape San Agustin. To the west of the gulf rise the gigantic Apo Volcano, the Matutan, and several other cones of less importance, which continue the northern boundary of the volcanic zone extending as it seems from Mt. Apo as far as the Celebes. The extensive valley of Agusan River runs from southeast to north, northwest almost parallel to the east coast of Mindanao. . . . . The entire bottom of the Agusan Valley consists of marine sediments containing an abundance of recent shells. Only at the mouths of the water courses which descend from the mountains, bounding it east and west, is found gravel containing well worn pebbles of andesite and other igneous rocks. Every geologist who has

[1] Fr. SADERRA Y MASO, Bull. P. I. Weather Bur., August (1910); July (1911).

visited this part of Eastern Mindanao receives the same impression, to wit, that its emergence from the sea is of quite recent date and its elevation is still increasing. Some of them assigned the Post-Pliocene period as the epoch of the formation of the sediment found in the Agusan Valley. . . . . This valley and the Davao Gulf appear to be portions of one and the same synclinal."

Line O begins near Placer on the northeast coast of Surigao peninsula and passes through an epicentre in Butuan bay and the northern course of the Rio Grande valley. This line seems necessary to explain the anomalous course of this river. Line O and line M seem to explain this satisfactorily.

Numerous other lines might be suggested, but we have included all for which we have any geological basis and a few others as suggestions.

DISCUSSION OF IMPORTANT EARTHQUAKES.

In discussing the various important earthquakes, little will be said about those previous to 1870, save the greatest, which occurred in 1645, but we shall consider the entire series represented by the charts published in "*La Seismologia en Filipinas,*" and discuss most of them separately.

Earthquake of 1645, Luzon, (3-9).[1]—This earthquake compares in magnitude with the greatest in the history of the world; its meizoseismic or epicentral area was not less than 490 kilometres from north to south, that is, from the southern coast of Batangas and Tayabas to the northern part of Cagayan. On the western coast it seems to have been of less intensity for the chronicles of the time are silent about its effects in these parts while they deal at length with the destruction caused in Manila and neighbouring provinces of the south, east and north, and with the tremendous effects produced as far north as Lalloc in the Cagayan valley and in the eastern part of the Central cordillera, that is, in Mountain province. That such an earthquake was due to tectonic movements cannot be doubted. Furthermore, it is very certain that it originated along a N.-S. line and that this line was within the island of Luzon and not beyond its eastern periphery; it may reasonably be supposed that it was along the seismotectonic line DD. It is a question whether the dislocations which then occurred along that line or fault were great enough to cause the many singular topographic features now existing along it in the provinces of Nueva Ecija, Nueva Vizcaya and Isabela. Moreover, as the city of Manila seems to have been very close to the point of origin of that memorable earthquake, our opinion is that some dislocations occurred at the same time along the fracture represented by the line HH. Similar cases of lines crossing each other are frequent in severe earthquakes. For example, the earthquake which occurred in 1870 was apparently of tectonic origin as it had its epicentre in the northwestern portion of Luzon, and might be explained as due to a displacement along the line AA.

The great number which occurred in 1871 were of volcanic origin, having as their epicentre the island of Camiguin. The destructive area included the

[1] Figures refer to Plate I, and indicate the location.

islands of Camiguin and Bohol, that part of Mindanao known as Misamis, and the southwest corner of Leyte.

Earthquakes of July 11th (3) *and of November 5th, 1871* (17).—These are both clearly of tectonic origin. The destructive area of the first comprises the Central cordillera of Luzon; and that of the second is located along line EE or, perhaps, the line PP.

Earthquake of December 29th, 1872 (7).—The destructive area comprises roughly that portion of Luzon adjacent to line FF, but it is possible that these disturbances originated from the Taal Volcano fracture. No eruption of Taal volcano is recorded for that year.

Earthquakes of August 25th (*22nd, 23rd*) *and October 16th, 1874* (8, 9).—In the former the destructive area comprises the Zamboanga peninsula, and is clearly tectonic, probably due to dislocations along the line II. In the second the destructive area comprises the region east of Manila bay, is more or less elongated north and south and possibly has some connection with the line DD. Taal volcano was probably not the cause of this disturbance.

Earthquakes of May 1st (7, 8) *and of July 5th, 1877* (10, 11).—The former was felt over most of southwestern Luzon. It probably emanated from Taal volcano and probably was due to movements propagated along the line GG, which follows the western limit of the central plain of Luzon. The latter may have been of volcanic origin, as the whole southeastern volcanic region is comprised in the destructive area, or it may have had its origin in some movement along the line marking the Philippine "deep" (XX).

Earthquakes of August 13th, 1878 (7, 8), *and of July 1st, 1879* (17).—The former seems to have had its epicentral area located near Manila bay, and to have resulted from disturbances along the line GG mentioned in the last paragraph. The latter had its destructive area in northeastern Mindanao and Surigao peninsula and was possibly due to the Agusan line or more probably to displacements along the line EE.

Earthquakes of July 14th and 25th, 1880 (5, 6, 8, 9,).—The destructive area shown on this chart indicates that the disturbances originated somewhere in the Eastern cordillera of Luzon. Two originated along line HH, and the third in the eastern part of Laguna province, line DD.

The earthquakes of July 25th, 1880 (5, 8, 9), show that the destructive area conforms pretty closely to that shown in Chart VII. (*La Seismologia en Filipinas.*) These should both be classed as tectonic.

Earthquakes of May 15th (4, 5, 6, 8) *and of July 11th, 1881* (15).—In the case of the former the destructive area is confined to the Eastern cordillera in north-central Luzon, and is clearly of tectonic origin. That of the latter had its centre on the island of Guimaras, just south of Panay. It is clearly of tectonic origin and was probably due to displacements along the contact between the Tertiary sediments of the western half of the island and the igneous rocks of the eastern half.

The earthquake of July 16th in Ilocos Norte province, Luzon (2), was undoubtedly due to disturbances along the line AA.

Earthquakes of September 10th, 1881 (5). The area of destruction [illegible] these earthquakes was very local, being in the southern part of [illegible] Vizcaya, and may be attributed to purely local causes, possibly rockfall.

The earthquake of September 30th, 1881 (4, 5), again centred in Nueva Vizcaya, and was probably of the same origin as the previous one.

Earthquake of April 30th, 1882 (7, 8). The destructive area was very local and was centred just north of Manila bay, but more to the west near the contact between the material of the valley floor and the volcanic rocks of the Zambales mountains; hence there seems to be some reason for conjecturing that it was due to tectonic causes. On September 12th, a very similar earthquake occurred in the same region.

Earthquakes of July 25th (7, 8) and 28 (2), 1882. During the former the epicentral area was situated between Taal volcano and the China sea, and hence may be of volcanic origin. That of July 28th was located along the cordillera of Luzon in the northern part, and hence may be called tectonic.

The earthquake of September 11th, 1882 (7) had its focus somewhere near Taal volcano.

Two earthquakes on September 17th (10) *and 21* (2, 3), *1882.* In the case of the former, the destructive area was centred about the southeastern volcanic cluster in Luzon. The latter had its epicentre in north-central Luzon, but the longitudinal axis of the destructive area runs slightly north of east. We do not know of any prominent structural line in that region running in that direction. The course of Abra river where it makes a sharp right-angle bend to the west in the latitude of Vigan, is suggestive of some prominent earth lineament. On September 6th, 1862, October 9, 1901 and May 25th, 1907, very similar earthquakes occurred in the same region, having their main line of propagation in nearly the same direction.

Earthquake of October 10th, 1882. The destructive area of this centred about San Miguel bay in southeastern Luzon (10). Very little is known about the formation on Caramoan peninsula so that we are unable to give any theory for the disturbances here.

Two earthquakes of February 10th (3, 4) *and of July 14th, 1883* (10).—The former originated in Nueva Vizcaya and probably was due to causes already mentioned. The latter earthquake clearly originated from volcanic disturbances, as the destructive area comprises the southeastern volcanic region of Luzon.

Earthquake of July 27th, 1883 (7, 8).—This was clearly volcanic, or at least related to the fracture passing through Taal, which is included in the destructive area.

Earthquakes of January 10th (10) *and March 22nd, 1884* (5).—Both of these were very likely of tectonic origin; one had its epicentre in the northwestern portion of Pangasinan province, where there is no sign of recent vulcanism. This probably is due to displacements along the line GG. The second one had its epicentre near the southeastern volcanic region, but on the west side of the peninsula, where there is a slight uplift of Tertiary sediments which may indicate tectonic causes. Lately, in 1907, there occurred two destructive earthquakes in the same region, probably due to the same causes.

Earthquake of April 20th, 1884 (7).—This was not destructive, but according to the distribution of the effects of the earthquake, it probably was of tectonic origin and can be attributed to displacements along the line GG.

Earthquake of October 29th, 1884.—This had two destructive areas (6, 8, 9) more or less separated, the epicentre of one being just north of Laguna de Bay, and the other just north of the southeastern volcanic cluster (10). There is no sign of a volcano at present north of Laguna de Bay, but it is probable that the line HH runs through this region.

Earthquakes of December 17th and 24th, 1884 (5, 13).—These were clearly of tectonic origin. In the former the displacement undoubtedly took place along the line CC, and that of the latter was probably due to movement along the line which runs N.W.-S.E. through the straits between Leyte and Samar, which is indicated by the line NN.

Only one earthquake (2, 3) is shown on this chart and that seems clearly to have originated along line AA.

Earthquakes of July 23rd and 24th, 1885 (5, 6).—The first seems to have had its epicentre northwest of Dapitan peninsula. In 1897 another destructive earthquake of the same origin occurred under the sea in the same region. It is very likely that this is of intertectonic origin, due to line II. There is no record of any volcanic demonstration emanating from Dapitan peninsula. It seems very clear from the great lineal extent of the destructive area of this earthquake north and south that the line II is responsible, hence this would be called tectonic. The earthquake of the 24th of the same month seems to be similar to that of December 17th, 1884.

Earthquake of November 16th, 1885 (7, 8).—This was clearly of volcanic origin as it seems to have been most generally felt in the southwest volcanic region of Luzon.

Earthquake of November 19th, 1885 (5).—This was similar to that of July 24th, 1885 and was also tectonic.

Earthquakes of April 10th (15) *and August 2nd, 1886* (7).—The first one was undoubtedly tectonic and is connected with the line JJ. The second may have been in part volcanic, but on account of its extension to the northwest, we believe that it can be referred to the tectonic line GG.

Earthquakes of February 1st (3) *and 2nd, 1887* (14).—The former seems to have been localized in north-central Luzon and may or may not have been tectonic. It is possible that this disturbance was due to rockfall. The latter earthquake seems to have affected the whole island of Panay, and was probably due to rockfall, because a recent examination has shown that landslides of considerable magnitude are of frequent occurrence on this island. In these two regions violent earthquakes of like character and probably of the same origin occurred in 1902 and 1904.

Earthquake of March 24th, 1887 (10).—This was unquestionably of volcanic origin and due to disturbances in the southeastern volcanic cluster of Luzon. The two earthquakes here shown of June 19th (6, 8) and October

1st, 1887 (10, 11, 12), respectively, were only light ones. The second one emanated from the same volcanic region as the earthquake just mentioned, but that of June 19th was undoubtedly of tectonic origin in the Eastern cordillera.

Earthquakes of June 27th (20, 21), *May 3rd* (2, 3) *and August 19th* (4), *1888.*— The first was undoubtedly tectonic as we know of no volcanoes anywhere in that portion of Mindanao, but neither do we know enough about the geology of that portion to say with any certainty that there is a tectonic line running at an angle to the main Agusan line. The reader is referred to an article by Fr. SADERRA MASO[1] on this subject. On Plate VIII of that paper the author has indicated the several epicentric areas near the "Philippine deep." Most of these areas are elliptical, with their long axes extending north and south or northwest and southeast, but one of these has its long axis extending slightly north of east to slightly south of west. The second seems to have had its centre in the cordillera of northern Luzon. The third is a clear case of movement along line DD, or Cagayan line.

Earthquakes of January 1st (17), *February 5th* (22, 23, 25), *May 26th* (7, 8), *and of October 6th, 1889* (17, 20, 21).— The first is clearly due to movements along line EE and the second along line MM. The third without question is due to the lines or fractures HH and FF. The fourth affected the whole Agusan Valley region, and the eastern coast can be attributed to the "Agusan line," or rather to the Pacific structural "deep."

In addition to the above list of earthquakes in the article *La Seismologia en Filipinas* we desire to add the following important earthquakes.

Earthquake of 1892, Pangasinan, Benguet, and La Union provinces (5).— The tectonic nature of this earthquake seems to be beyond doubt, since it occurred in a region where no recent volcanic formations are found. The northern part of its epicentral area comprises the uplands of Baguio, where the tremendous upheavals which occurred in recent geologic periods are clearly evident. Almost in the centre of the epicentral area rises Santo Tomás, an andesite block-mountain due in part to faulting, while in the southern part lies the alluvium of the Pangasinan plains. It seems highly probable that the cause of this earthquake can be found in some important dislocation which occurred near the Santo Tomás mountain mass. This epicentre belongs to line CC.

Earthquake of 1893, Agusan valley, Mindanao (20).— This is unquestionably the greatest earthquake which has occurred in this region during the last three centuries. The permanent sinking of part of the floor of the valley and the faulting on the divide between the headwaters of Agusan valley and the Gulf of Davao suggests a folding movement of the Eastern cordillera as a whole or a slip toward the east in connection with the changes which possibly occurred in the deep trough running along the east coast. This earthquake must be classified as most typically tectonic, as it occurred along a very definite structural line.

[1] *Seismic centers of Samar, Leyte and Eastern Mindanao;* from the Bull. P. I. Weather Bur., August (1910).

Earthquakes of 1897.—The natural and fearful happenings of this year bring to the mind the somewhat fabulous occurrences of 1641, when earthquakes in Luzon occurred at the same time as eruptions in Mindanao, Jolo, and Sanguir. During this year destructive tectonic earthquakes were felt in northern Luzon (2), northern Samar (11), Masbate (12), eastern and western Mindanao (19, 22, 23, 24), while as a climax Mayon volcano experienced one of its worst eruptions. The most typical and important of these earthquakes was that which occurred in western Mindanao. Its origin or epicentral area seems to have been under the sea, west of Zamboanga peninsula, where two very important lines, LL and DD, intersect. It must be considered as one of the most memorable of Philippine earthquakes on account of the most extraordinary seismic wave ever felt in the archipelago. Furthermore, it seems to have been connected with the rising of some temporary islands near the northwest and northeast coasts of Borneo.

Earthquake of 1902, Illana Bay, Mindanao (23).—This shook heavily the districts of Cotabato and Lanao; its epicentral area comprised part of the bay, where the telegraphic cables were broken and buried under mud, the eastern coast and plain of Cotabato and the northern coast with the uplands of Lanao district as far as the lake. In this last region there had been great volcanic activity during the Tertiary period as is shown by the basalt and lava flows which cover it, and by some old volcanic cones that rise toward the south and east; but during the historic period only one doubtful eruption is reported. Consequently, considering the wide extension of this earthquake and its effects upon land and the bottom of the sea, it should be classified as tectonic and connected with line MM.

PRACTICAL CONSIDERATIONS.

1. The fact of the instability of the earth's crust has been proved time and again both by tremendous catastrophes and by laboratory experiments. It has been demonstrated that many of these devastating earth movements have taken place along definite lines of weakness in the crust. The location and extent of these lines can usually be fairly accurately determined by a geological examination.

2. The points of intersection of such lines are dangerous, as can be shown by an examination of the province of Calabria in Italy.[1]

3. Volcanoes are only incidental phenomena and are results rather than causes. They are usually found to be lined up along some rift line.

4. Points of danger in the archipelago are:

a. Along the Taal rift line from the town of Lemery to Los Baños on Laguna de Bay, and possibly farther to the northeast.

b. All "made" land. The California Earthquake Commission (1908)

[1] W. H. Hobbs, *Some Principles of Seismic Geology;* Beiträge zur Geophysik, Bd. VIII, Heft 2, S. 224.

reported that the intensity of the shocks and the destruction were greatest and the amplitude of the waves longest in the "made" ground.[1]

c. The Agusan valley, Mindanao.

d. The Straits of San Juanico.

e. The district northeast of Manila near the east coast and northwest of the island of Polillo. Three prominent lines intersect in two places close together in this region.

f. That part of Batangas peninsula which ends in Cape Santiago.

5. Types of structures best suited to Philippine conditions:

a. Bamboo houses. These are so built that they are all tied together and behave like a basket. They are strong, elastic and light and act like a single piece of material.

b. "Strong material," a term locally used to distinguish wooden, well-nailed houses from bamboo structures. Floor joists well anchored.

c. Sand-lime brick tied to steel frame; this should be cheaper than concrete and in case of warping walls can be removed easily and replaced by new steel.

d. Reinforced concrete; perfectly safe if properly made, but expensive and apt to receive permanent warping and fissuring[2] from the twisting motion of some earthquakes.

e. Ordinary brick walls with roof of unanchored tiles make one of the worst possible types of construction, as demonstrated at Messina.

6. The necessity of geological examinations of all dams, pipelines and bridge sites should be emphasized. Tremendous damage was done to these kinds of engineering structure in the San Francisco earthquake. It is well known that the breaking of the water mains by the earthquake left the city at the mercy of the fires which shortly broke out.

7. The harbours of Cebu, Iloilo, and Zamboanga, owing to their approximating in shape to a funnel or double funnel, are more or less in danger from tidal waves.

8. Manila harbour, owing to the comparatively small entrance and rapidly widening basin, should be quite safe in this respect.

SUMMARY AND CONCLUSIONS.

1. There is a close relationship between seismic disturbances and geological structure.

2. The majority of earthquakes are of tectonic origin, in the Philippines at least.

3. Volcanoes are secondary phenomena.

4. The area of greatest seismicity in the archipelago is in the Agusan valley, Mindanao.

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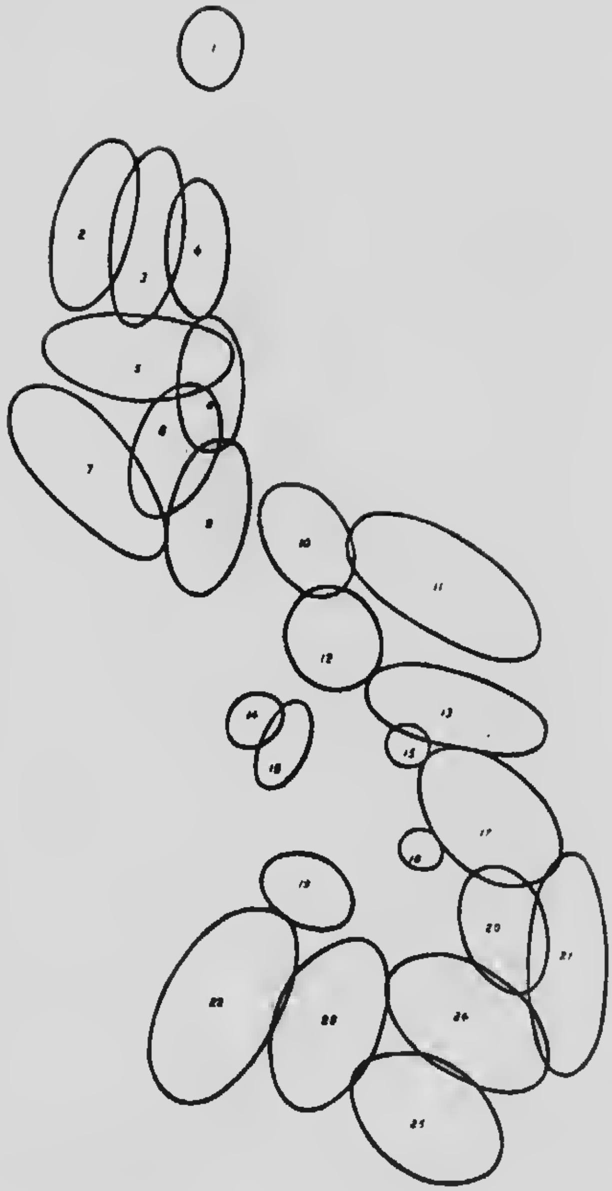
[1] *Report of California Earthquake Commission*, Washington (1910).

[2] In the severe Sorsogon earthquake, November, 1912, a new school house of reinforced concrete and concrete blocks was considerably damaged in both portions, the reinforced concrete portico sustaining considerable fissuring.

5. There is a close relationship between the orographic and other geomorphic lines and the lines connecting the principal epicentres in the archipelago.

6. Seismic disturbances can be studied and disasters can, to a large extent, be avoided.



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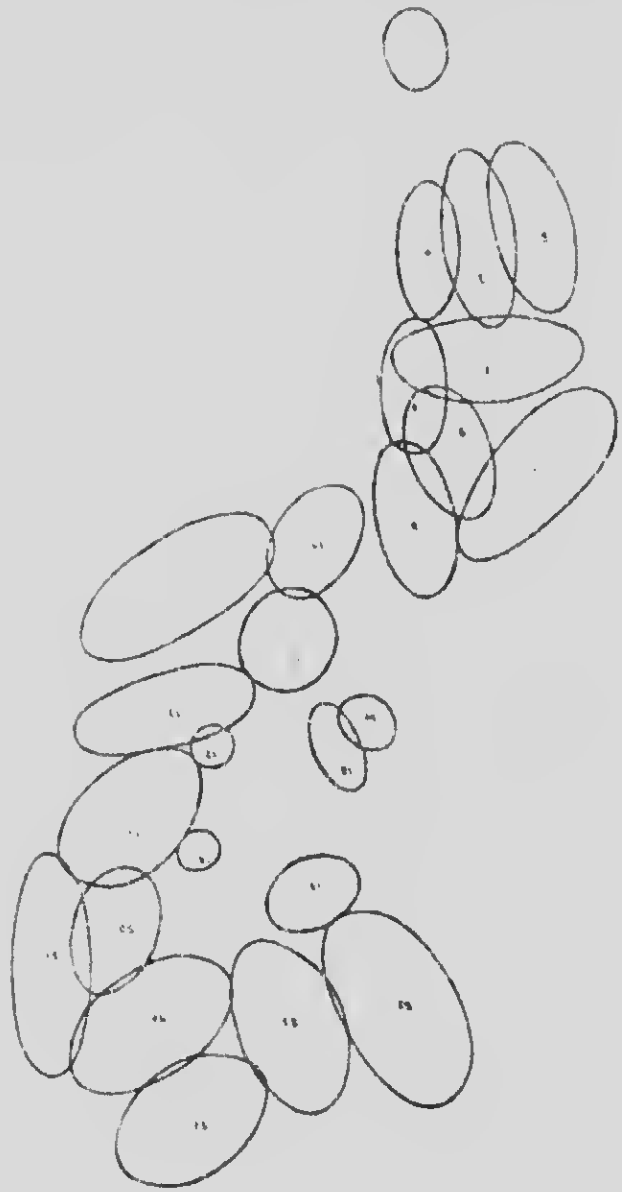

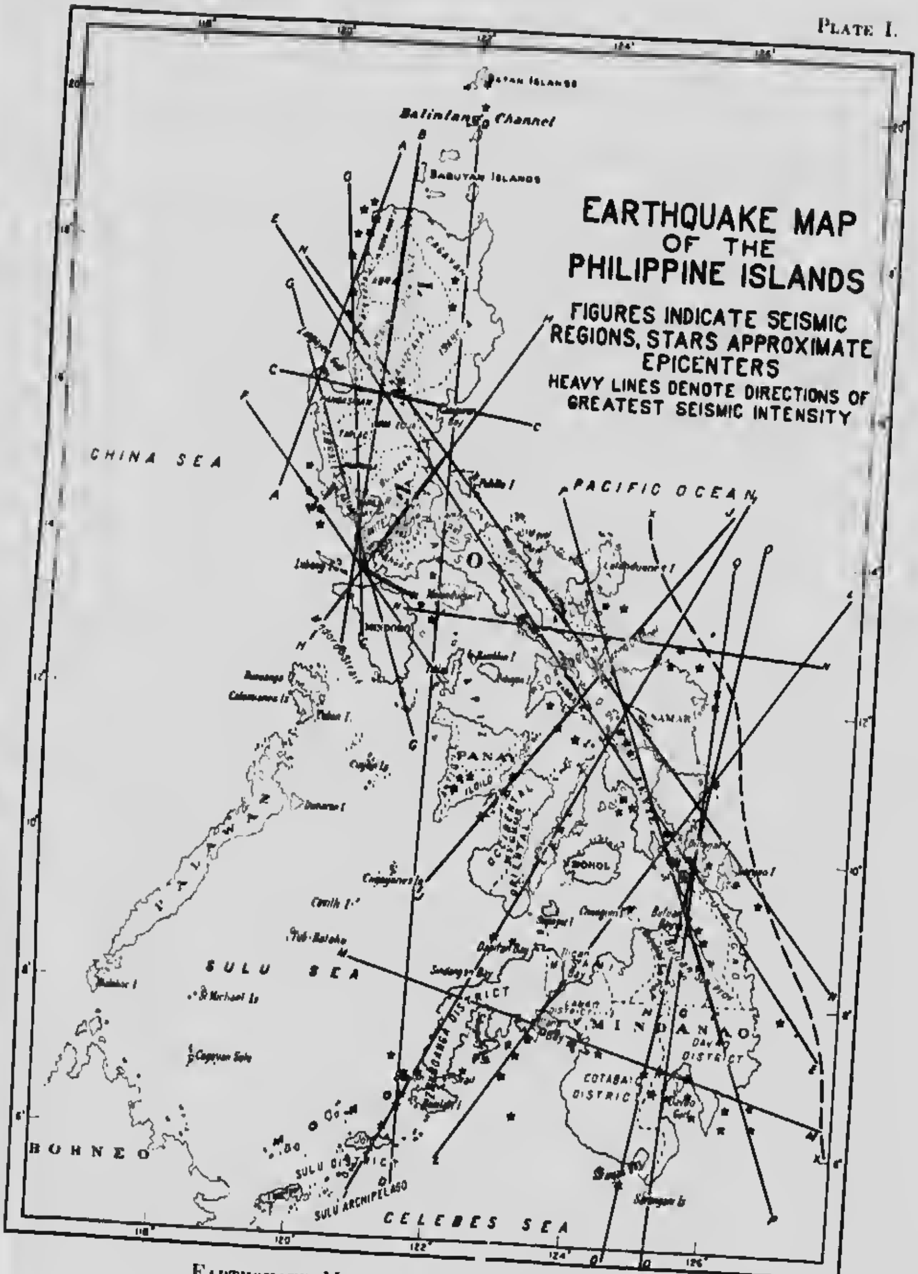

Earthquake Map of the Philippine Islands.

ÜBER TEKTONISCHE EXPERIMENTE.

VON

W. PAULCKE,

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Mein Vortrag über tektonische Experimente in Toronto ging Hand in Hand mit einer eingehenden Lichtbilderdemonstration des von mir konstruierten tektonischen Apparates und Darstellungen der mit demselben bei verschiedenster Versuchsanordnung gewonnenen Resultate, nach kurzer historischer Einleitung über früher von anderer Seite, i. sp. von J. HALL, A. FAVRE, M. READE, H. M. CADELL, BAILEY WILLIS u.a. unternommene Versuche.

Da eine Wiedergabe aller oder auch nur eines Teiles der Versuchsergebnisse im Bilde an dieser Stelle ausgeschlossen ist, muss ich mich damit begnügen, ein kurzes Autorreferat zugeben, in dem die allgemeinen in Betracht kommenden Gesichtspunkte dargelegt sind. Im Übrigen verweise ich auf meine *ausführliche Publikation* (*Das Experiment in der Geologie*, Berlin, 1912, Verlag von Gebr. BORNTRÄGER), in der sich auch Darstellungen der früher konstruierten Apparate und der mit ihnen erzielten Ergebnisse, sowie Literaturangaben, finden.

Der Hauptgrundsatz, von dem ich ausging, war: Ermöglichung von Versuchsanordnungen, die—soweit dies überhaupt in menschlicher Macht steht—*natürliche Bedingungen* möglichst getreu nachzuahmen versuchen. Alle bislang gebauten tektonischen Apparate—welche mir z. T. erst nach Ausführung meiner Versuche bekannt wurden—haben den grossen Fehler, dass die tektonischen Vorgänge in einem schmalen Kanal eingezwängt vor sich gehen (u.a. starker Reibungswiderstand der Seitenwände) und nicht auf breiter Fläche. Mit Ausnahme des Apparates von BAILEY WILLIS ist ausserdem die Wahl eines relativ starren Materials nie durch entgegenwirkende Belastung kompensiert, und auch bei diesem Autor ist die Belastung nicht variationsfähig. *Änderungsmöglichkeiten des Untergrundes* waren bislang *überhaupt nicht* in tektonische Versuche einbezogen worden, trotzdem, meines Erachtens, die variable *Beschaffenheit des Untergrundes* im Vorland, im Faltungsgebiete selbst wie im Hinterland vor, während und nach dem tektonischen Vorgänge mit von ausschlaggebender Bedeutung ist. Wir müssen also nicht nur das zu dislozierende Material, sondern auch seine Belastung und den Untergrund, auf dem es ruht und von dem es umgeben ist, in möglichst weitgehender Weise variieren können. *Ausweichmöglichkeiten* und *Widerstände*, z. B. alte Horste und vorhandene Gräben oder Depressionen, haben fraglos die Tektonik unserer Faltengebirge auf das stärkste beeinflusst, ebenso *Hebungen, Aufpressungen und Senkungen* in Gebieten vorherrschend horizontaler Bewegungen, und zwar während und nach denselben.

Ein brauchbarer tektonischer Apparat muss also die genannten Forderungen erfüllen. Kräftiger Horizontalschub muss in dem Apparat natürlich auf die darin eingebrachten Massen wirken können. Variation in der Wahl und Anordnung des zu dislozierenden Materials ist bis ins Unendliche möglich.

Mein Versuchsapparat ist schwer aus Eisen gebaut, damit auch bei Verwendung starreren Materials starke Belastung angeordnet werden kann. Die Versuchsfläche, der Boden auf dem das zu dislozierende Material angeordnet wird, weist 12 Versenkungs- bezw. Hebungskästen auf, die im Niveau des sie umschliessenden Rahmens als glatte, horizontale Ebene bleiben, bezw. einzeln oder in Gruppen vermittelst Spindeln gesenkt oder gehoben werden können. Es können also *vor* der Sedimentation, *während oder nach* derselben, Gräben (längs oder quer) hergestellt oder Horste bezw. lokale Aufpressungen geschaffen werden. Schwere, abnehmbare Eisenwände umgeben die Versuchsfläche und erlauben eine Belastung bis über 16000 kg. Mittels zweier gekuppelter Druckspindeln wird eine Druckwand vorgeschoben (Erzeugung des horizontalen tangentialen Druckes). Als Material wählte ich verschieden gefärbte Gips- und Tonschichten, deren verhältnismässig grosse Starrheit und Dicke durch *starke Belastung* wenigstens z. T. zu *kompensieren* versucht wurde.

Man kann nun Versuchsreihen derart ausführen, dass man nacheinander ganz einfache Verhältnisse in verschiedensten Richtungen variiert:

1. *Variationsreihen in der Art der Sedimentation.*
2. *Wechsel in der Art der Gestaltung des Untergrundes:* (a) vor, (b) während, (c) nach Einwirkung des tangentialen Schubes.
3. *Wechsel in der Art der Belastung.*
4. Die *Gruppen 1-3 mit einander kombiniert.*

Man kann aber auch den Versuch machen, *einzelne Beispiele in der Natur* nachzuahmen, um auf diese Weise die Richtigkeit hypothetischer Ansichten über bestimmte tektonische Vorgänge in bestimmten Gegenden zu prüfen. Ich habe vor der Hand den letzteren Weg gewählt und nacheinander versucht, im Prinzip die Tektonik (1) *des Faltenjura;* (2) *der helvetischen Kalk-Ketten der Alpen;* (3) *der lepontinisch-ostalpinen Alpengebiete* experimentell nachzuahmen.

VERSUCH A. NACHAHMUNG DES FALTENJURATYPUS.

Die *Stratigraphie* war durch einen einfachen Wechsel härterer und weicherer Schichten nachgeahmt worden. Dann wurde im Vorlande, etwa 86.5 cm vor der beweglichen Druckwand, eine 77 cm breite, 29 cm lange und 3 cm tiefe Quersenkung vorgenommen, während an jeder Seite dieses Senkungsgebietes je 11 cm ungesenkten Gebietes stehen blieben. Dann erfolgte der Zusammenschub unter mässig starker Belastung.

Das Ergebnis war: Bildung von zwei Antiklinalen und Ansatz einer dritten im Senkungsgebiete, sowie *Bündelung* derselben zu *einer* Falte in der Region der nicht gesenkten Seitenregionen, wo infolge des Stauungswiderstandes jederseits einfache Falten-*überschiebung* eintrat.

Das experimentell gewonnene Bild entspricht also im Prinzip in wichtigen Zügen dem Bilde des Faltenjura mit seinen gebündelten Falten, welche im Süden und Osten schliesslich in je *einer* Falte endigen, die im Gebiet nahen, stauenden Widerstandes als deutliche Faltenüberschiebung ausgebildet sind. Gegen das Pariser Becken, in der grossen Lücke zwischen französischem Zentralplateau einerseits, sowie Schwarzwald und Vogesen andrerseits, fluten dagegen die Wellen des Jura in reichlichem Faltenwurf vor, ein Bild welches sich ja bekanntlich im Kleinen nochmals zwischen Schwarzwald und Vogesen in der Pfirt wiederholt.

Im Grossen haben wir also im Experiment wie in der Natur, Reduktion der Faltenzahl und Bündelung, z. T. Überschiebung im Gebiet der stauenden Widerstände und Entwickelung reichlicher Falten in der Region leichter Ausweichmöglichkeit (Depression). Im Einzelnen finden sich im geschilderten Experiment noch weitere Analogien in deutlicher Rückwärtsüberkippung der inneren Antiklinale und in rückwärts gerichteten Überschiebungen, die sich besonders in den harten Schichten des Inneren der Antiklinale zeigen.

Erwähnung soll an dieser Stelle der Versuch CADELLS finden, welcher einen Schichtenkomplex auf einem lose auf seiner Unterlage liegenden biegsamen Wachstuchstreifen anordnete. Beim Zusammenschub ergab sich naturgemäss ein Abschieben der Schichten einschliesslich Wachstuch von der Unterlage und die Bildung von typischer *Kofferfaltenform*. Die resultierenden tektonischen Bilder gemahnen stark an die Darstellungen des Jura als "Abscheerungsdecke" durch BUXTORF. Es ist daher wohl möglich, dass der "Kofferfaltenbau" typisch für eine von der Unterlage abgescheerte Decke auf glatter Unterlage ist.

VERSUCH B. NACHAHMUNG ALPIN-HELVETISCHER TEKTONIK.

Die *Stratigraphie* war im allgemeinen ähnlich gewählt wie beim Juraexperiment, d.h. ein Wechsel härterer und weicher Gesteine (Ton an Gips) in ziemlich regelmässiger Folge. Die *Belastung* war dagegen *beträchtlich stärker* über dem ganzen Areal und überdies war in einer (rückwärts gelegenen) Region durch Einschaltung einer biegsamen Metallplatte, welche mit vorgeschoben wurde, das Ausweichen der Schichten nach oben besonders erschwert worden. 86,5 cm vor der beweglichen Druckwand erfolgte eine quer zur Druckrichtung verlaufende Hebung in 77 cm Breite und 29 cm Länge im Betrage von 27 mm.

Das Ergebnis war ein sehr interessantes. Faltungen wurden ausgelöst:

1. In Region I, dem Gebiete der Hebung im Vorland.
2. In Region II, hinter Region I.
3. In Region III, vor der beweglichen, schiebenden Druckwand, unter der erwähnten Metallplatte, hinter Region II. Der Typus der tektonischen Bewegungen war in den drei genannten Regionen ein verschiedener.

In *Region I* hatte die gehobene Barriere als Stauungswiderstand gewirkt; es kam zu einer aus einfacher Antiklinale hervorgegangenen Faltenüberschiebung vom Juratypus. Die Ähnlichkeit dieser Überschiebung mit der Hombergüberschiebung beim Hauenstein ist sehr gross.

In *Region II* hatte die vordere Antiklinale als Stauungswiderstand gewirkt. Dicht hinter der normalen Faltenüberschiebung kam es zur Abspaltung der oberen harten Schicht und ihrer tonigen Unterlage und zu relativ weitgreifender Überschiebung dieser nur zwei Schichten umfassenden „*Spaltdecke*" über die vorliegenden obersten Schichten gleicher Art. Dicht dahinter kam es *in Region II* nochmals zur Bildung einer, diesmal drei Schichten umfassenden „Spaltdecke," bei der von besonderem Interesse die *sekundäre Bildung einer antiklinalen Umbiegung am Stirnrande*, hinter dem stauend wirkenden Vorlande, ist.

Das Profil durch diese Zone zeigt, dass die sogenannten „Tauchdecken", Säntisdecke, Simplondecken etc., welche am Stirnrand antiklinale Umbiegungen zeigen, diese Umbiegungen erstens einem stauenden Widerstande, einer „Stauchung" verdanken dürften, weshalb ich vorschlage sie „*Stauchdecken*" zu nennen, und dass sie zweitens, wenn wir keine Reste eines ausgequetschten Mittelschenkels nachweisen können, *nicht aus Überfaltungen* hervorgegangen sind, *sondern Spaltdecken darstellen*, deren Stirnrand sich eingerollt hat, der seine *antiklinale Umbiegung* erst *sekundär* erhielt. Das Experiment hat hier überaus wertvolle Hinweise für die Deutung solcher Profile gebracht.

Die hinter der soeben geschilderten Region II gelegene *Region III* zeigt gleichfalls sehr wertvolle Profile; es kam hier zur Bildung von *Überfaltungsdecken* mit mehrfacher Wiederholung der Schichten übereinander. Dieser Typus entstand in einer Schichtserie mit abwechselnden harten und weichen Schichten und—was von ausschlaggebender Bedeutung ist—in der Region *stärkster Belastung* und *geringster Ausweichmöglichkeit* nach oben. Die *Stilähnlichkeit* mit gewissen helvetischen Deckengebieten ist auffallend. Charakteristisch ist auch im Experiment, wie in der Natur, *das antiklinale Zurückbleiben der älteren*, als liegende Falten gelagerten *Schichten*, von denen die jüngeren beim Vortreiben der Bewegung gleichsam abgestreift worden sind. Mit natürlichen Vorkommnissen stimmt weiter das—auch bei anderen Experimenten auftretende—starke lokale, wie regionale Anschwellen der weichen, nachgiebigen Schichtkomplexe zum vielfachen ihrer primären Mächtigkeit überein.

Schon bei diesen Versuchen über helvetische Tektonik treten auch beim Experiment Komplikationen in Gestalt von *Einspiessungen, Durchstechungen, Verschleppung* harter Gesteinskomplexe, Steilstellung und Überklappen einzelner Schollen statt, und wir vermögen im Experiment viele tektonische Unregelmässigkeiten, wie wir sie, ohne sie deuten zu können, in unseren Gebirgen finden, *im Zusammenhang zu erkennen* und *in ihrer Genese* zu begreifen. Das Experiment führt uns also hier zur Klarheit in der Deutung der Entstehung verwickelter Lagerungsverhältnisse, über deren Entstelungsmöglichkeiten bislang nur vage Vermutungen bestanden, die z. T. sehr weit auseinandergingen.

VERSUCH C. NACHAHMUNG OSTALPIN-LEPONTINISCHER TEKTONIK.

Wir sehen in der Natur, dass jedes faziell gut charakterisierte Gebiet eines Gebirges eine seiner petrographisch-faziellen vorherrschenden Ausbildung entsprechende typische Tektonik aufweist. Ich spreche daher von der Entwickelung „*tektonischer Stilarten.*" Den *jurassischen* und den *helvetischen Stil* haben wir in den Experimenten A und B in der Genese verfolgt. Versuch C sollte zur Ausbildung des so charakteristischen *ostalpin-lepontinischen Stils* führen.

Die „Deckenhypothese" nimmt an, dass in der Region der jetzigen Alpen einstmals sehr verschieden ausgebildete Fazies *hintereinander lagen* und dass diese auch petrographisch sehr verschieden ausgebildeten Sedimentzonen durch tangentialen Schub *abeinander* geschoben worden sind. Während die *helvetische Fazies* mit ihrem mehr oder weniger regelmässigen Wechsel von harten und weichen Gesteinen *zu* mehr oder weniger gut ausgebildeter *Faltungstektonik neigt*, weist die vorwiegend aus mächtigen harten Kalken und Dolomiten bestehende *ostalpine Fazies* in den Alpen vor allem *Überschiebungstektonik* auf und in den weichen tonigen Komplexen der *lepontinischen Serie* ist es zu einer überaus *wirren Tektonik* gekommen, besonders da, wo extrem harte und extrem weiche Gesteine mit einander in Berührung kamen.

Bei *Versuch C*, welcher zweimal mit gleichem Ergebnis wiederholt wurde, ordnete ich *drei verschiedene Fazies hintereinander* an: vorn helvetischen Typus, Wechsel harter und weicher Schichten; dahinter lepontinischen Typus mit dominierenden weichen, tonigen Schichten, und schliesslich dahinter eine die ostalpine vertretende harte Fazies.

Zu fordern war, dass durch tangentialen Zusammenschub *eine Tektonik* resultiere, *welche im Prinzip der ostalpin-lepontinischen gleich*. Die Ergebnisse waren nun in beiden Parallelversuchen überraschend gute. Bei einem Gesamtvortrieb der Druckwand um 56 cm *wanderte die harte ostalpine Fazies sofort 40 cm* (!) über die weiche lepontinische als *glatte Überschiebung (keine Faltung!)*.

Der tektonische Vorgang löste sich an der Faziesgrenze aus. Im Einzelnen entwickelten sich eine Fülle von tektonischen Vorgängen, die zu Bildern von Profilen führten, wie wir sie sowohl aus dem ostalpinen wie aus dem lepontinischen Gebiete, als auch aus den Grenzgebieten zwischen beiden kennen.

Im „ostalpinen" Gebiet ergaben sich, ausser glatten Deckenüberschiebungen, *Schuppen* mit schrägen Überschiebungsflächen, wie *doppelte* und *dreifache Wiederholungen desselben harten Niveaus* mit fast horizontaler Überschiebung.

Im Grenzgebiete beider Fazies sehen wir *Durchstechungen* der harten Fazies durch die weiche.

Die *Region der weichen lepontinischen Fazies* schliesslich zeigt Faltungen und Fältelungen der weichen Tonschichten, z.T. Stauchungen zum Vielfachen ihrer primären Mächtigkeit. Weiter sehen wir Durchstechungen härterer Schichten durch weichere, eine *vollkommene Mischung* der verschiedenen Niveaus zu *wirrster Lagerung*, wie sie uns aus der lepontinischen Region der Alpen nur zu bekannt ist, wo ihre Entwirrung so grosse Schwierigkeiten bereitet. Aus dem Gesagten ergibt sich, dass meine bisherigen Versuche schon Ergebnisse gezeitigt haben, welche es ermöglichen, uns Klarheit über die Genese der verschiedensten tektonischen Erscheinungen in der Natur zu verschaffen. Wir werden durch das Experiment einesteils in die Lage versetzt die bis jetzt im Felde gewonnenen Anschauungen auf ihre Richtigkeit und mechanische Möglichkeit zu prüfen. Wir lerner aus dem Vergleich der experimentell gewonnenen Ergebnisse mit Naturprofilen bisher nicht in ihren Zusammenhängen richtig gedeutete Profile umzudeuten, bezw. Klarheit über ihre Genese zu gewinnen; wir sind im Stande Vermutungen auf ihre Richtigkeit zu prüfen, und eine Identität der Ergebnisse beim Versuch mit theoretischen Schlussfolgerungen, die im Felde gewonnen wurden, nimmt den letzteren ihre hypothetische Unsicherheit.

Die Wirkung aller möglichen bei tektonischen Vorgängen in Betracht kommenden für die Art der Gestaltung ausschlaggebenden Momente, wie z. B. Art der Sedimentation, Faziesfolge, Hebungen, Senkungen, eingeschaltete Widerstände, Belastungsintensität, Aufweichmöglichkeiten u.s.f. kann im Experiment geprüft werden.

Es ist eine bekannte Tatsache, dass die Ansichten über die Entstehung unserer Gebirge *sehr weit auseinandergehen*, und dass selbst in der Deutung der Lagerungsverhältnisse gut studierter, kompliziert gebauter Gebiete, wie der Alpen, die grössten Meinungsverschiedenheiten herrschen; ja, bei manchen Erklärungsversuchen werden sogar tektonische *Hypothesen* laut, *die mechanisch unmöglich* sind und trotzdem ihre Anhänger finden. Da kann schliesslich allein das Experiment Klarheit schaffen. Wir müssen lernen unsere *theoretischen Vorstellungen durch das Experiment zu kontrollieren.* Meine bisherigen Versuche haben als erste Ansätze zu weiterer Ausgestaltung dieses bisher unverdientermassen so vernachlässigten Forschungszweiges zu gelten. Nachdem inzwischen Königsberger und Morath die Frage tektonischer Experimente von der physikalischen Seite in Angriff genommen haben, sollen die Versuche auf Grund der bisher von mir und von den genannten Autoren gewonnen Ergebnisse fortgeführt werden, wobei das Hauptbestreben sein muss, die Versuchsbedingungen immer mehr den in der Natur herrschenden Verhältnissen anzunähern, soweit das überhaupt in menschlicher Macht steht.

Der von C. Rimbach (Neues Jahrbuch für Mineralogie, etc., Beil. Bd. XXXV), eingeschlagene Weg scheint mir wenig glücklich gewählt, da Versuchsapparat und Versuchsanordnung sowie Materialwahl kaum mit natürlichen Verhältnissen verglichen werden können.

Die bisherigen Erfahrungen und weitere Überlegungen haben mich in Verbindung mit Dr. Morath dazu geführt, meinen bisherigen tektonischen Apparat so zu modifizieren, dass er noch weiteren Anforderungen an die

Natürlichkeit der Versuchsanordnung gerecht wird, wobei auch Material gewählt werden wird, welches—nach MORATHS Berechnungen—auf eine der Modellgrösse entsprechende Festigkeit reduziert ist.

Der Zweck meines Vortrages war, an der Hand der bereits gewonnenen günstigen Ergebnisse zu zeigen, welcher Wert schon jetzt systematisch unternommenen tektonischen Versuchen innewohnt und darauf hinzuweisen, wie entwickelungsfähig dieser Zweig unserer Wissenschaft ist. Wir stehen erst in den ersten Anfängen einer rationell betriebenen Experimentalgeologie.

Contributions diverses: Géologie économique et chimique, et mineralogie.

ERGEBNISSE DER GEOLOGISCHEN UNTERSUCHUNGEN DER PHOSPHORITLAGERSTÄTTEN RUSSLANDS.

VON

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Mit einer Tafel.

Eine der wichtigsten Aufgaben, mit denen die Agrikultur sich heute zu befassen hat, ist die Frage über die Mineraldüngung des Ackerbodens. Für Russland, einen von jeher ackerbautreibenden Staat, wird diese Frage zur Grundaufgabe, umsomehr als auch hier die unausbleibliche Intensivierung der Landwirtschaft nach und nach in seine Rechte greifen muss und greift.

Unter den mineralischen Düngstoffen kommt, wie bekannt, die grösste Bedeutung den phosphorsauren Düngemitteln zu, deren Ausgangsmaterial die Phosphorite sind.

Die Frage über die Vorräte dieses nutzbaren Minerals, des Phosphorits, im Bereich Russlands wurde früher in ganz bestimmten Sinne beantwortet. Vielfach wurde der von A. S. YERMOLOW im Anfang der siebziger Jahre des vorigen Jahrhunderts ausgesprochene Gedanke wiederholt, dass Russland mit seinen Phosphoriten „pourrait empaver la moitié de l'Europe, tant les couches, qu'elle renferme, sont inépuisables de richesses." Mit einer solchen bildlichen Schätzung schien die Frage abgetan zu sein. Die Arbeit YERMOLOWS liegt auch den Ansichten über den Reichtum Russlands an Phosphoriten einer ganzen Reihe von Autoren zugrunde, wie PENROSE, MÜNTZ et GIRARD, DE LAUNAY, STELZNER-BERGEAT, STUTZER und andere.

In letzter Zeit wurde jedoch immer häufiger und häufiger der Gedanke ausgesprochen, dass der ausschliessliche Phosphoritreichtum Russlands unbewiesen sei und dass jedenfalls genaue Forschungen über die Lagerstätten dieses Fossils angestellt werden müssten.

Das Bedürfnis nach Gewissheit rief denn im Jahre 1908 die Organisation einer besonderen Kommission an der Moskauer Landwirtschaftlichen Hochschule ins Leben, welche sich eine allseitige Erforschung der Phosphoritvorkommnisse Russlands zum Ziel gesetzt hatte. Gleichzeitig mit der geologischen Erforschung der Phosphoritlagerstätten Russlands, deren Leitung mir anvertraut wurde, unternahm diese Organisation Untersuchungen über die chemische Verarbeitung der Phosphorite in Produkte, welche von Pflanzen leichter assimiliert werden können (Superphosphat, Präzipitat), und stellte Vegetationsversuche an.

Während der ersten zwei Jahre (1908-1909) war der Umfang der geologischen Arbeiten ein beschränkter: es waren dies Versuchsarbeiten, durch welche die Untersuchungsmethoden erprobt und die weitere, umfangreichere Organisation ausgearbeitet wurden.

Seit 1910 wird die Organisation zweckmässig bedeutend erweitert und sie setzt ihre Arbeit bis heute ununterbrochen fort. An den geologischen Arbeiten beteiligen sich eine ganze Reihe von Forschern: A. Archangelsky, P. Bajarunas, G. Burenin, S. Dobroff, A. Iwanoff, A. Kasakoff, A. Krasowsky, O. Lange, W. Lutschizky, G. Mirtschink, A. Netschaeff, T. Nikschitsch, A. Pavloff, M. Prigorowsky, A. Rosanoff, A. Roschkowsky, A. Samjatin, A. Semichatoff, N. Tichanowitsch, M. u. P. Wasiljewsky, A. Winokuroff.

Vier Bände unserer „*Geologischen Untersuchungen über die Phosphoritlagerstätten Russlands*" sind bereits im Druck erschienen und in kürzerster Zeit wird der Band V veröffentlich werden.

Die Resultate der geologischen Feldarbeiten, welche in unseren Berichten eingehend beschrieben sind, werden auf eine 10-Werstkarte aufgetragen. Wo die Phosphoritführung besonderes Interesse erregt, werden die Resultate, falls man über die notwendige topographische Grundlage verfügt, auch in grösserem Maassstabe dargestellt.

Qualitativ werden die Phosphorite aus verschiedenen Vorkommnissen charakterisiert: (1) durch eine eingehende, makroskopische, wie mikroskopische mineralogische Beschreibung des Fossils; (2) durch die Bestimmung seines chemischen Bestandes.

Chemisch untersucht werden bald isolierte Phosphoritknollen, bald die Phosphoritschicht als Ganzes, besonders wenn die Isolierung der Knollen von dem einschliessenden Gestein bei etwaigem Abbau der Lagerstätte technische Schwierigkeiten bieten würde. Der Zement wird analysiert, welcher die Phosphoritknollen zusammenkittet, ferner die Phosphoritknollen verschiedener Generation, kurzum man ist bestrebt ein klares Bild über den Phosphorsäuregehalt und die Verteilung derselben in der Phosphoritschicht zu gewinnen.

Phosphorithorizonte, welche besondere Aufmerksamkeit beanspruchen, werden nicht nur auf den Durchschnittsgehalt an P_2O_5 und unlöslichem Rückstand untersucht, sondern es wird auch das Vorkommen von Kohlensäure und Eisen- und Aluminiumoxyd bestimmt, um dem Mineral vom landwirtschaftlichen Standpunkt aus eine genauere Charakteristik zu geben.

Die Phosphoritlagerstätten werden *quantitativ* charakterisiert: (1) durch Bestimmung der Ausdehnung der Phosphorithorizonte in natürlichen Entblössungen und, wo nötig, mittelst kleiner künstlicher Aufschlüsse. (2) durch Bestimmung der Mächtigkeit der Phosphoritschicht. Da die Phosphoritknollen gewöhnlich in einer Schicht tauben Gesteins eingeschlossen sind, beschränkt sich die Bestimmung nicht auf die Angabe der Mächtigkeit der Schicht, sondern es wird die ganze Menge des nutzbaren Materials aufgewogen, welches in einer Flächeneinheit enthalten ist—die Phosphoritmenge in Kilogrammen auf einen Quadratmeter Fläche. Mittelst dieser Zahl wird die *Produktivität* einer Phosphoritschicht charaekterisiert.

Schliesslich wird eine eingehende Schilderung der Lagerungsverhältnisse der Phosphoritschichten gegeben mit detaillierter Charakteristik des Hangenden, des Liegenden und des Wasserregims.

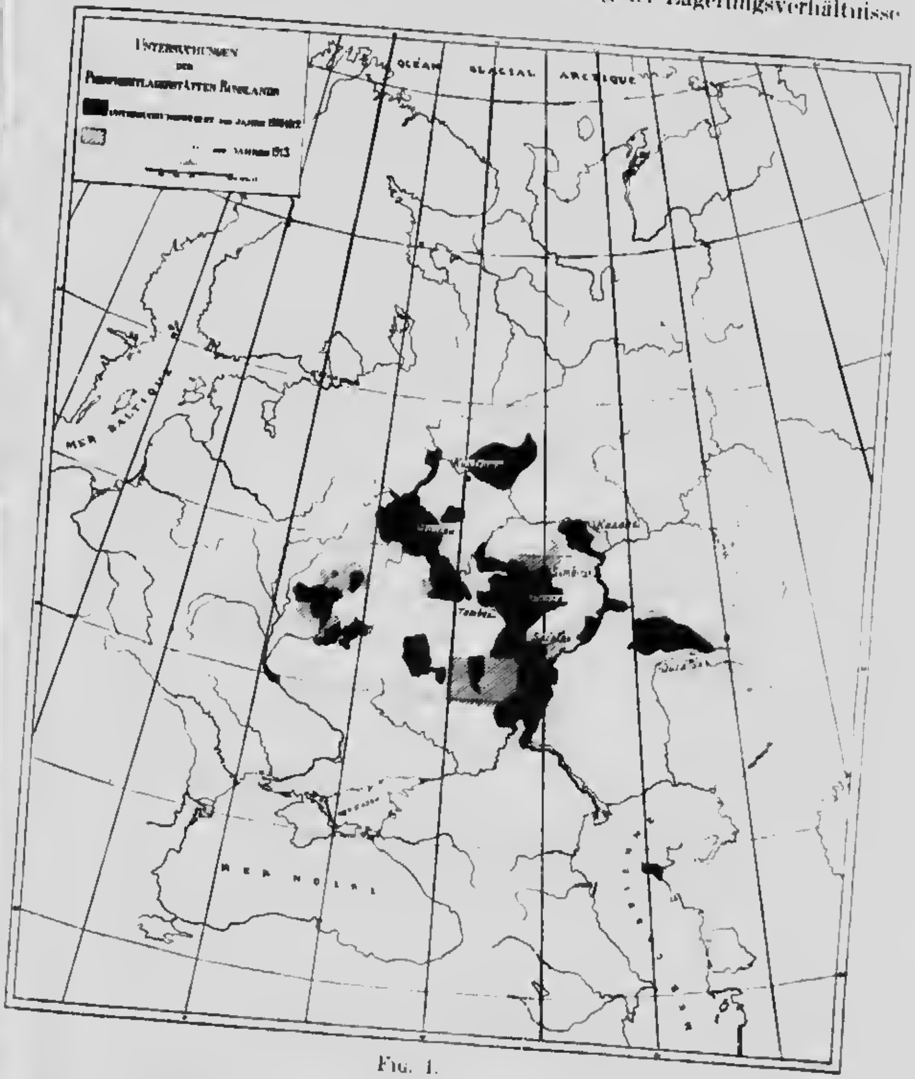


Fig. 1.

Die geologischen Forschungen begannen im östlichen Teil des Europäischen Russlands und beschränkten sich vorerst hauptsächlich auf die östlichen Gouvernements. In dieser Wahl wurden wir, abgesehen von manchen anderen Gründen, auch dadurch geleitet, dass die östlichen Vorkommnisse, unter gleichen übrigen Bedingungen, ihrer geographischen Lage nach verhältnismässig grösseren Wert besitzen, als die westlichen.

Eine Reihe von Umständen im Zusammenhang mit der Organisation der Arbeiten und der vorangehenden Verarbeitung des Materials zwecks Aufsetzung des Arbeitsplans für das nächstfolgende Jahr, sowie die wissenschaftliche Individualität der Mitarbeiter, erlaubten nicht eine ununterbrochene Aufnahme der Phosphoritlagerstätten auszuführen, veranlassten uns vielmehr einige Bezirke auszuscheiden, welche in manchen Teilen nunmehr schon aneinander stossen.

Auf der beigelegten Karte (Fig. I) sind die Flächen angezeigt, welche auf ihre Phosphoritlager hin von uns bereits erforscht sind. Die Untersuchungen des laufenden Jahres sind Schraffiert wiedergegeben.

Die Forschungen unfassen folgende Gouvernements: Samara, Orenburg, Uralsk, Saratow, Simbirsk, Pensa, Tambow, Kasan, Kostroma, Yaroslawl, Twer, Moskau, Smolensk, Wladimir, Rjasan, Gebiet des Donischen Heeres, Woronesh, Kursk, Tschernigow, Kiew und Halbinsel Mangyschlak.

Dem geologischen Bau nach können im Europäischen Russland alle Gebiete ausgeschieden werden, in welchen Phosphoritführung ausgeschlossen ist und die daher unseren Forschungen nicht unterliegen. Das übrige Areal bildet jenes Gebiet, dessen Erforschung wir uns zur Aufgabe gestellt haben. Ein Teil dieses Gebiets wird durch detaillierte geologische Aufnahmen untersucht werden müssen, während man sich in anderen Rayons auf kürzere Excursionen beschränken kann.

Dem Gang der bereits ausgeführten Arbeiten nach zu urteilen, könnten die Forschungen, in gleichem Tempo fortgesetzt, etwa in 2-3 Jahren zum Abschluss gebracht werden.

Die untersuchten Phosphoritlagerstätten Russlands gehören dem oberen *Jura*, der *Kreide* und zum kleinsten Teil auch dem untersten Abschnitt des *Tertiär*systems an.

Aus leicht verständlichen Gründen kann ich mich eben mit der Charakteristik der einzelnen Phosphorithorizonte, selbst in allgemeinen Zügen, nicht befassen.

Um jedoch eine Orientierung zu ermöglichen, führe ich hier an:

1. Geologische Profile einiger der wichtigsten untersuchten Phosphorithorizonte (Fig., a, b).
2. Mikrophotographien von Schliffen verschiedener Phosphorite (Tab).
3. Volle chemische Analysen der Phosphorite einiger Horizonte (s. Tab. I).

Die von unserer Organisation ausgeführten Arbeiten umfassen bereits ein bedeutendes Areal des Europäischen Russlands, doch sind eben noch eine Reihe interessanter Vorkommnisse unerforscht geblieben, so z. B. das bekannte eigenartige Phosphoritvorkommniss von Podolien mit seinen primären Phosphoritknollen in silurischen Tonschiefer und sekundären Lagern in Kreidegesteinen. Diesem Vorkommnis ist eine umfangreiche Literatur gewidmet und es wird seit langer Zeit bereits abgebaut. Unberücksichtigt geblieben ist ferner das neuerdings aufgefundene genetisch

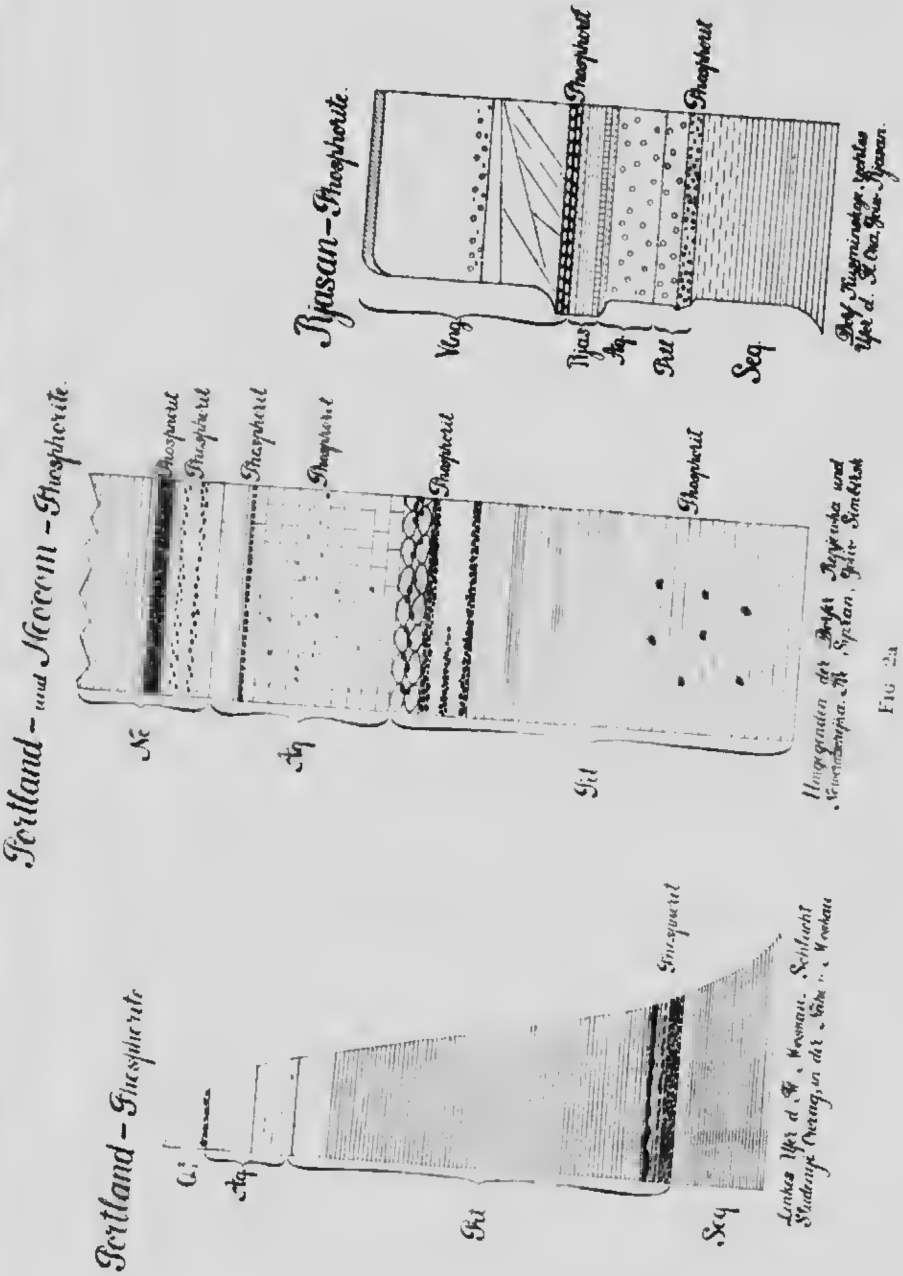

Rjasan-Phosphorite.
Portland- und Neocom-Phosphorite.
Portland-Phosphorite
Phosphorit

Fig. 2a.

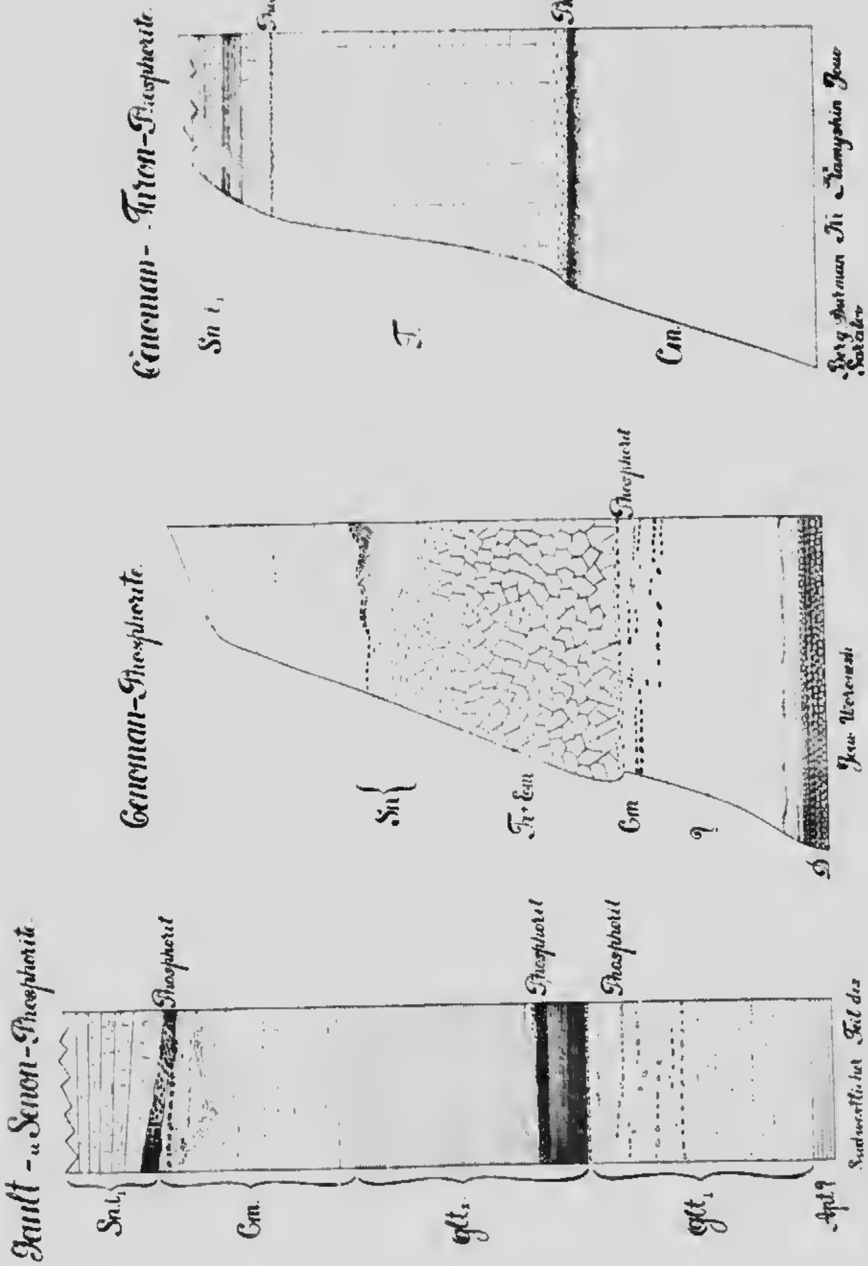

Gault - u Senon-Phosphorite.
Sn.i1
Cm.
glt.
glt1
Apt?
Phosphorit
Phosphorit
Phosphorit
Sudwestlicher Teil des Gouv. Kiewa
Cenoman-Phosphorite.
Sn
Tr+Cm
Cm
?
D
Phosphorit
Gouv. Woronesh
Cenoman- Turon-Phosphorite.
Sn i1
T.
Cm.
Phosphorit
Phosphorit
Berg Burman Ki Kamyshin Gouv. Saratow

Fig. 2b.

J. SAMOJLOFF

TAFEL I

1. Rjasan Phosplorit, Suchar Nowoselki. Vergr. 50.
2. Cenoman Phosphorit. Staryj Gorod [illegible] Kursk. Vergr. 30.
3. Gault Phosphorit, Simbirsk.
4. Gault Phosphorit, Kamenka. Vergr. 60.
5. Portland Phosphorit, Moskau, Petrowsko-Rasumowsko. Vergr. 55.

sehr interessante, an Granite gefundene, uralische Phosphoritvorkommen in der Gegend von Ekaterinburg, dessen Wert weit noch ganz unaufgeklärt ist.

Wenn auch unsere Arbeiten noch nicht zu Ende geführt sind, sind sie doch bereits so weit vorgeschritten, dass das allgemeine Bild der Phosphoritlagerstätten Russlands heute recht präzise Formen annimmt.

Um die Orientierung in den gewonnen Resultaten zu erleichtern und die Möglichkeit zu geben, sich ein Gesamtbild über die Verteilung der Phosphoritlager auf dem untersuchten Areal zu schaffen, wird hier eine schematische Übersichtskarte beigelegt, auf welcher die Ergebnisse unserer

	Portland-Phosphorit. Petrowsko-Rosmnowskoje Moskau.	Aquilon-Phosphorite Gouv. Kostroma.		Gault-Phosphorite. Gouv. Saratow	
		Unter Sch	Ober. Sch	Seugilej	Kruterkij Buerak
Na_2O	0.99	0 74	0 59	1.40	0 38
K_2O	0 92	0 31	0 33	1 43	0 56
MgO	0 82	0 64	0 69	1 19	1 30
CaO	39 08	44.60	47 07	28 24	32 52
MnO	Sp.	......	. .	0 62	0 56
Al_2O_3	1 70	2 60	1 64	4 85	1 60
Fe_2O_3	1 67	1.34	1 26	2 29	1 29
F	1 82	3.28	2.97	1 68	1 49
Cl	.	Sp.	Sp.	.	
CO_2	5 47	5 54	11 72	2 40	2.89
SiO_2	0.47	0.40	0.14	33 42	36 15
SO_4	...	0.99	0.87	1 48	1 27
P_2O_5	21 51	28 98	25.10	18 21	19.88
FeS_2	2.52	0 60	0 72	1 55	0 71
Unlöst	19 43	2 96	0 76	.	
Organ.	0 61	7.96	7 72	0 69	0 68
H_2O	....			1 91	0.75
H_2O bei 105	...	0 90	0 73		
Verlust	3 91	... .	...	...	
	100 92	101 87	102 31	101 36	102 03
Ab O für F.	0 76	1.38	1.25	0 71	0 63
	100 16	100.49	101 06	100 65	101 40

Tabelle 1: Chemische Analysen der Phosphorite einiger Horizonte.

Arbeiten, wenngleich in groben Zügen, so doch in übersichtlicher Form von bestimmten Standpunktaus aufgetragen sind.

Als topographische Grundlage wählten wir die 60-Werstige Karte, welche, wie, bekannt, auch dem Geologischen Comité als Grundlage für seine geologische Übersichtskarte des Europäischen Russlands dient.

Auf den Karten, welche unsere genauen Berichte über die ausgeführten Untersuchungen begleiten, werden nur die tatsächlichen *Aufschlüsse* der Phosphoritschichten aufgetragen. Auf die Übersichtskarte angewandt, würde dieses Prinzip zu einer Reihe technischer Schwierigkeiten führen.

die Karte würde viel an Übersichtlichkeit verlieren und es würde uns doch nicht gelingen den schematischen Charackter zu vermeiden, welchen der geringe Massstab derselben (60 Werst im Zoll) unumgänglich nach sich ziehen muss. Aus dem angeführten Grunde entschlossen wir uns dazu auf die Übersichtskarte die Lagerungsflächen der Phosphoritschichten aufzutragen.

Bei der Zusammenstellung einer solchen Karte mussten, wie leicht vorauszusehen, eine Reihe von Fragen auftauchen, welche sich zuweilen leicht beantworten liessen, zuweilen jedoch grosse Schwierigkeiten der Ausführung unserer Aufgabe entgegensetzten.

Nicht selten sind Fälle, wo die Phosphoritschicht, mit deren Erforschung wir uns befassten, unter das Niveau der fliessenden Gewässer sinkt und unserer Beobachtung entzogen wird. Die gewöhnlichen geologischen Untersuchungsmethoden geben keine Aufklärung über den weiteren Gang der Schicht; Schürfungen oder Bohrungen jedoch werden durch den Charakter unserer Arbeiten ausgeschlossen, so dass uns kein Material über die genaue Verbreitung der Schicht ausserhalb der Grenze des Beobachtungsfeldes zur Verfügung steht, obgleich das Vorhandensein derselben jenseits dieser Grenze keinem Zweifel unterliegt. In dergleichen Fällen wird auf der Übersichtskarte nur die Grenze selbst angezeigt, längs welcher die Schicht unserer Beobachtung entzogen wird, und zwar mittelst einer *punktierten* Linie.

Wie bekannt, unterscheiden sich die Phosphoritschichten des Europäischen Russlands stark voneinander, sowohl der Qualität, als auch der Quantität des nutzbaren Minerals nach, welches auf eine Flächeneinheit fällt (Produktivität). Daher würde eine gleichartige Bezeichnung aller Phosphoritschichten auf der Karte ein recht unklares Bild von den Phosphoritreichtümern Russlands geben. Die Phosphorite mussten in Gruppen zusammengefasst werden.

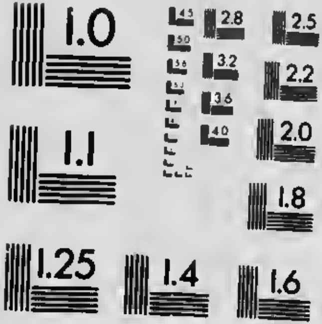
Zur *qualitativen* Charakteristik der Phosphorite wählten wir drei Farben, um drei verschiedene Gruppen auszuscheiden: (1) mit blauer Farbe werden Phosphoritschichten mit 12–18 % P_2O_5 bezeichnet, (2) mit roter Farbe solche mit 18–21 % und (3) mit grüner Farbe Schichten, deren P_2O_5 Gehalt 21 % übersteigt.

Die Einteilung der Phosphorite gerade in die genannten drei Gruppen ist natürlich in gewissem Grade subjektiv, doch entspricht die gewählte Gliederung mehr oder weniger den Unterschieden im geologischen Charakter dieser drei Phosphoritgruppen und grenzt Phosphorite voneinander ab, welche vom technischen und agronomischen Standpunkt aus mehr oder weniger ausgeprägte Unterschiede aufweisen, wie dies von Spezialisten, den Agronomen unserer Organisation festgestellt werden konnte.

Die Bedeutung der Phosphorite, als nutzbares Mineral, wird jedoch nicht allein durch die Qualität, sondern auch durch die Quantität bedingt. Um die *quantitative* Charakteristik der Phosphoritschichten auf der Karte wiederzugeben, wurde gleichfalls eine Gliederung in drei Gruppen gewählt: eine Phosphoritshicht, welche nur durch eine der drei Farben ohne weitere

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



Zeichen wiedergegeben ist, entspricht einer Produktivität der Schicht von 100-200 kg. Falls auf einen Quadratmeter nur 50-100 kg Phosphorite fallen, werden auf die mit einer bestimmten Farbe bezeichnete Fläche Striche — (Minuszeichen) aufgetragen; dagegen wird die Produktivität einer Phosphoritschicht, wenn sie 200 kg. übersteigt, durch + (Pluszeichen) wiedergegeben.

Jene Gebiete, wo die Phosphorite unseren Forschungen zufolge in Qualität oder Quantität hinter den festgestzten Grenzen zurückbleiben, werden auf der Übersichtskarte gelb bezeichnet. Diese Kategorie schliesst folglich die Gebiete ein, in welchen die Phosphorite vielleicht zwar in grosser Menge vorhanden sind, doch unter 12% P_2O_5 enthalten, oder auch Gegenden mit Phosphoriten von hoher Qualität, doch mit ganz unbedeutender Produktivität, welche 50 kg. nicht überschreitet.

Bei manchen Phosphorithorizonten spielt eine ausserordentlich grosse Rolle der Charakter der *Zementierung* des Horizontes, d. h. ob die Phosphoritknollen lose im lockeren fremden Gestein liegen und folglich leicht vom Nebengestein abgetrennt werden können, oder ob sie zu einer dichten Masse zusammengekittet sind und sich nicht auf gewöhnlichem Wege ablösen lassen. Ein und derselbe Horizont, welcher im ersten Falle ein quantitativ und qualitativ befriedigendes Material ergiebt, kann beim Auftreten von Zementierung seine Bedeutung verlieren, da jetzt die ganze zu gewinnende Gesteinsmasse in Rechnung gezogen werden muss und folglich der P_2O_5—Gehalt bedeutend sinkt (unter unsere äusserste Norm von 12%).

Gewöhnlich sind wir nur in der Lage die Phosphoritschichten in natürlichen Entblössungen zu studieren, d. h. wir haben ein Material vor uns, welches in der Verwitterungszone liegt. Hier können auch verschiedene Fälle auftreten in Abhängigkeit vom mineralischen Charakter des Zements: lockeres Material kann unter der Einwirkung der Verwitterungstagentien fest werden, und umgekehrt dichtes Material locker. Diese höchst interessante mineralogische Frage ist von grosser praktischer Bedeutung und verdient in Bezug auf die Phosphoritlagerstätten weiter durchgearbeitet zu werden.

Nicht gering ist ihre Bedeutung ferner auch für die Beurteilung des Hangenden und Liegenden der Phosphoritschicht.

Falls die Verbreitungsflächen der freiliegenden Phosphoritknollen und der zementierten Massen genau bestimmt werden können, werden sie dementsprechend auch auf der Karte aufgetragen. In menchen Gegenden jedoch ist die Verteilung derartiger zementierter und lockerer Partien keiner Gesetzmässigkeit unterworfen: ein Grundstück löst das andere ganz willkürlich, unerwartet und in geringster Entfernung ab. Die Grenzen der einen und der anderen zu bestimmen ist unmöglich, und dann wird auf der Karte das ganze Gebiet schematisch durch Schraffierung in entsprechender Farbe bezeichnet. So ist z. B. das Verbreitungsgebiet der untersenonen Phosphorithorizontes in den südwestlichen Kreisen Kerensk und Tschembar des Gouvernements Pensa durch rote und gelbe Schraffierung gekennzeichnet: freiliegende Knollen mit 16-21% P_2O_5 und schwankender Produktivität (ca. 180kg.) werden durch ein dichtes zementiertes Gestein mit durchschnittlich 10% P_2O_5 Gehalt abgelöst.

Die Lagerung einer Phosphoritschicht, welche durch ein isoliertes Bohrloch nachgewiesen ist, wird schematisch durch einen blauen, roten oder grünen Kreis, seiner Qualität entsprechend, bezeichnet.

Im folgenden wird der Versuch gemacht die auf der Karte graphisch abgegrenzten Phosphoritlager in Zahlenform wiederzugeben und eine ungefähre Berechnung der Vorräte der Phosphorite, wie sie durch die Arbeiten unserer Organisation nachgewiesen wurden, auszuführen.

Selbstredend müssen alle Einschränkungen und Bedingungen, welche beim Auftragen der Phosphoritlager auf unsere Karte berücksichtigt wurden, in vollen Masse auch auf den Zahlenansdruck dieser Lager bezogen werden. Sogar weitere Schwierigkeit traten uns dabei hindernd in den Weg. Genauer bestimmt musste, z. B., werden das Mass der späteren, sekundären Zerstörung jener Lager durch Erosion und Gletscher, welche einst auf diesem oder jenem Grundstück vorhanden waren und nachträglich vernichtet wurden. Dadurch erklärt sich in manchen Fällen, dass der Zahlenausdruck für ein Phosphoritlager der Grösse der entsprechenden Fläche unserer Karte nicht voll entspricht (kleiner ist), da der Masstab natürlich nicht erlaubt kleine erodierte Grundstücke auszuscheiden.

Aus der weiter angeführten Berechnung wurden die Areale ausgeschlossen, welche auf der Karte mit gelber Farbe bezeichnet sind, d. h. Phosphoritschichten mit weniger, als 12% P_2O_5 Gehalt oder mit einer Produktivität, die geringer als 50 kgm ist.

Die angeführten Zahlen zeigen die Menge der Phosphorite in den von unserer Organisation untersuchten Gebieten an, wobei in manchen Rayons die Zahlen annähernd der ganzen vorhandenen Menge entspricht, in anderen nur einen minimalen Teil einschliesst (vergl. z. B., die Areale, welche auf der Karte von punktierten Linien begränzt werden).

Entsprechend den geologischen Eigentümlichkeiten der einzelnen Untersuchungsgebiete (Charakter des Reliefs, Zahl der Entblössungen etc.) nähern sich die angeführten Zahlen in verschiedenem Masse der wirklichen Grösse unserer Vorräte an Phosphoriten.

In allen weiter folgenden Berechnungen wurden von der ganzen Phosphoritmenge jene Vorräte nicht abgeschieden, welche *heute*, als praktisch abbauwürdig anerkannt werden können. Der praktische Wert für einen bestimmten Zeitpunkt wird, wie bekannt, nicht allein durch die geologische Charakteristik der Schicht (Qualität, Produktivität, Lagerungsverhältnisse) bestimmt, sondern auch durch eine Reihe von Ursachen montan- und chemischtechnitchen Charakters (heutiger Stand der Technik bei der Verarbeitung der Phosphorite), sowie durch Ursachen ökonomischen Charakters, die sämtlich in Raum und Zeit manigfaltig ineinandergreifen.

Entsprechen der Klassifikation, welche vom Institute of Mining and Metallurgy in London vorgeschlagen wurde, müssen unsere Berechnungen zur Gruppe des probable ores (wahrscheinlich vorhandenes Erz) gestellt werden.

In den folgenden Tabellen sind für die einzelnen Rayons angeführt:

TABELLE II.

Abkürzungen: Kl.—Kellaway; Oxf.—Oxford; Km.—Kimmeridge; Prt.—Portland; Rjs.—Rjasan-Korizont; Ne.—Neocom; Glt.—Gault; Cm.—Cenoman; T.—Turon.

GOUVERNEMENTS.	% Gehalt P_2O_5.	Produktivität.	Fläche in qklm.	Phosphorit—Menge in MT.	P_2O_5—Menge in MT.
COUV. KOSTROMA.					
Zwischen d. Fl. Kistega, Wolga u.d. D. Porosowo. Aq.	26	180	23	4 1	11
Rechtes Ufer d. Wolga von Kineschma bis Reschma. Aq.	25	145	227	38.8	8.2
Linkes Ufer d. Wolga von Kineschma bis zur Mitte d. Wasserscheide der Fl. Shelwat u. Nemda.	"	125	545	68 8	17 2
Rechtes Ufer d. Fl. Unsha von Koslowskoje bis Nowoselki. Aq.	12–18	360	273	98.3	14 7
Rechtes Ufer d. Fl. Neja von Nowoselki bis Wlasowo. Aq.	20–22	180	91	16.4	3.4
Rechtes Ufer d. Fl. Neja von Beresniki bis Polubesowo. Aq.	18–20	125	68	8.6	1.6
Rechtes Ufer d. Fl. Unsha von yarzewo bis Swinaja Noga. Aq.	23	"	91	11.5	2.6
Rechtes Ufer d. Fl. Unsha von Swinaja Noga bis Rilisowo. Aq.	19	250	148	37.3	7.1
GOUV. YAROSLAWL.					
Wolga, zwischen Myschkin und Rybinsk. Km.	12–16	180	511	92.1	12.9
GOUV. MOSKAU.					
Fl. Moskau, Marjino und Moshinka, Kr. Swenigorod. Prt.	20–25	145	7	1.0	0.2
Fl. Pachra u. Nebenfl. Motscha u. Desna, Kr. Podolsk. Prt.	"	200	739	146.4	32.9
Fl. Pachra, Moskau u. ihre rechten Nebenfl. Kr. Bronnizy. Prt.	"	"	307	60.8	13.7
Fl. Moskau u. ihre Nebenfl. Kr. Moskau. Prt.	"	235	273	63 9	14.4
Recht. Ufer. d Fl. Osenka, Sewerka, Moskau u. link. Uf. Kolomenka, Kr. Kolomensk Prt..	"	250	20	5.2	1.2
Kolomna. Prt.	"	180	8	1.4	0.3
Recht. Ufer. d. Fl. Kolomenka.					
GOUV. KALUGA.					
Fl. Nara, Kr. Borowsk. Prt.	"	720	28	20.5	4.6
GOUV. RJASAN.					
Westlicher Teil, Kr. Egorjewsk. Prt.	"	200	284	56.3	12.7
Umgeg. v. Kusminskoje, Kr. Rjasan. Rjs.	19–22	720	23	16.4	3.4
Umgeg. v. Kusminskoje, Kr. Rjasan. Prt.	19	500	"	11.4	2 2

TABELLE II.—*Fortgesetzt.*

Abkürzungen: Kl.—Kellaway; Oxf.—Oxford; Km.—Kimmeridge; Prt.—Portland, Rjs.—Rjasan-Horizont; Ne.—Neocom; Glt.—Gault; Cm.—Cenoman; T.—Turon

GOUVERNEMENTS.	% Gehalt P_2O_5.	Produktivität.	Fläche in qklm.	Phosphorit-Menge in MT.	P_2O_5-Menge in MT.
Umgeg. v. Kusminskoje, Kr. Rjasan. Konglomerat. Prt.	21	215	11	2.5	0.5
Umgeg. v. Pesotschna, Nowoselki u. Garetnaja, Kr. Rjasan. Rjs.	"	500	15	7.5	1.6
Umgeg. v. Pesotschna, Nowoselki u. Garetnaja, Kr. Rjasan. Prt.	"	250	19	4.9	1.0
Umgeg. v. Staraja Rjasan (Spassk), Kr. Spassk. Rjs.	18–20	"	68	17.2	[illegible]
Umgeg. v. Staraja Rjasan (Spassk), Kr. Spassk. Rjs.	27	70	"	4.9	1.3
Umgeg. v. Michajlow, Swistowo u. Poslodowo, Kr. Michajlow. Rjs.	20	510	18	9.8	2.0
Umgeg. Michajlow, u. Ponatowo, Kr. Michajlow. Rjs.	21	575	6	3.3	0.7
Umgeg. Pronsk, Kr. Pronsk, Rjs.	20	665	2	1.5	0.3
Umgeg. v. Pokrowskoje, Kr. Pronsk u. Skopin. Rjs.	18	235	6	1.3	0.2
Umgeg. v. Podedinki, Kr. Skopin, Rjs.	14	215	7	1.5	"
Umgeg. v. Michei, Kr. Saposhok, Rjs.	19	290	2	0.7	0.1
Umgeg. v. Aleschna, Kr. Sarajsk, Sandstein. Aq.+Prt.	22	360	1.	1.6	0.4
Umgeg. v. Aleschna, Kr. Sarajsk, Gerölle, Prt.	23	90	"	0.4	0.1
Umgeg. v. Tregubowo, Kr. Sarajsk, „Suchar." Aq.+Prt.	17	395	6	2.2	0.4
Umgeg. v. Tregubowo, Kr. Sarajsk, Gerölle. Prt.	23	90	"	0.5	0.1
Umgeg. v. Belynitschi, Kr. Sarajsk. Prt.	14	290	"	1.6	0.2
Umgeg. v. Raduschino, Kr. Sarajsk. Prt.	22	"	4.5	1.3	0.3
Umgeg. v. Sarajsk, Kr. Sarajsk. Prt.	"	"	2	0.7	0.1
Umgeg. v. Topki, Kr. Ranenburg. Rjs.	21	575	6	3.3	0.7
GOUV. KASAN.					
Gebiet der Berge Irarsk, unweit Abysowo, Kr. Yadrinsk. Prt.	23–27	115	2	0.3	0.1
GOUV. TAMBOW.					
Linkes Ufer. d. Fl. Mokscha, Kr. Elatma. Ne.	20	"	8	1.1	0.2
GOUV. PENSA.					
Nördlicher Teil d. Kr. Insar u. Saransk. Ne.	21–25	90	300	27.1	6.8
Linkes Ufer d. Fl. Mokscha, Kr. Krasnoslobodsk. Ne.	21–22	360	83	29.8	6.4

TABELLE II.—*Fortgesetzt.*

Abkürzungen: Kl.—Kellaway; Oxf.—Oxford; Km.—Kimmeridge; Prt.—Portland; Rjs.—Rjasan-Korizont; Ne.—Neocom; Glt.—Gault; Cm.—Cenoman; T.—Turon.

GOUVERNEMENTS.	% Gehalt P_2O_5.	Produktivität.	Fläche in qklm.	Phosphorit-Menge in MT.	P_2O_5-Menge in MT.
GOUV. SIMBIRSK.					
Umgeg. v. Repjewka u. Noworatschejka, Kr. Syzran. Prt.	21	325	32	10.1	2.2
Umgeg. v. Repjewka, Noworatschejka u. Keschpur, Kr. Syzran. Ne.	15-18	360	83	29.8	1.9
GOUV. SAMARA.					
Umgeg. v. Orlowka, Kr. Nikolaewsk. Aq.—Ne.	21	170	6	2.8	0.6
Umgeg. v. Grischkino, Tarpanowka u. Danilowka, Kr. Busuluk. Kl.—Oxf.	15-22	145	114	16.4	3.0
GOUV. SAMARA U. GEB. URALSK					
Gebiet d. B. Ohtschyi Syrt (Oberlauf d. Fl. Tananik bis Talowaja. Kr. Busuluk u. Uralsk. Kl.—Oxf.	"	"	511	73.7	13.6
GEB. URALSK.					
Wasserscheide d. Nebenflüsse d. Fl. Ural u. Irtek. u. d. Fl. Tschegan, Kr. Uralsk. Kl.—Oxf.	"	290	227	65.5	12.1
GOUV. WORONETZ.					
Umgeg v. Soldatskoje u. Bogdanowka, Kr. Nishnedewizk. Cm.	12-14	360	28	10.2	1.3
Rechtes Ufer d. Fl. Sm. Dewiza, Umg. v. Sm. Dewiza, Kr. Woronesch.	"	290	6	1.6	0.2
Rechtes Ufer d. Don, zwischen Golyschewkau. Seljawnoje. Cm.	"	"	23	6.6	0.9
Rechtes Ufer. d. Don, „Schatristsche," Kr. Ostrogoshsk. Cm.	12-14	360	1	0.4	0.05
Rechtes Ufer. d. Don, Stschutschje, Perejesshaja u. Kolybelka, Kr. Ostrogoschsk. Cm.	"	290	40	11.5	1.5
Nishnuja Grajworonka, Kr. Semljansk. Cm.	12-15	215	6	1.3	0.2
Alisowo, Kr. Semljansk Cm.	"	250	14	3.4	0.5
Uspenskoje u. Werchotopje, Kr. Semljansk. Cm.	"	145	12	1.7	0.2
Golaja Snowa, Kr. Semljansk. Cm.	"	540	26	13.8	1.9
Rechtes u. linkes Ufer. d. Fl. Weduga,	"	360	86	31.2	4.2
Star. Weduga, Kr. Semljansk. Cm.	"	290	30	8.7	1.2
Stadniza, Kr. Semljansk. Cm.	"	540	29	15.7	2.1
Kiewka, Kr. Semljansk. Cm.					

TABELLE II.—*Fortgesetzt.*

Abkürzungen: Kl.—Kelloway; Oxf.—Oxford; Km.—Kimmeridge; Prt.—Portland; Rjs.—Rjusan-Korizont; Nc.—Neocom; Glt.—Gault; Cm.—Cenoman; T.—Turon.

GOUVERNEMENTS.	% Gehalt P_2O_5.	Produktivität.	Fläche in qklm.	Phosphorit—Menge in MT.	P_2O_5—Menge in MT.
Yundowistsche, Kr. Semljansk. Cm.	12–15	360	6	2.2	0.3
Linkes Ufer. d. Fl. Smerd. Dewiza. Kr. Nishnedewizk. Cm.	"	180	77	13.8	1.9
GOUV. KURSK.					
Nordwestlicher Teil d. Kr. Dmitriew.	"	360	131	47.0	6.3
GEB. DES DONISCHEN HEERES.					
Bespdemjanowskij. Kr. Choper. Cm.	15–17	235	6	1.3	0.2
Lysogorskij, Kr. Choper. Cm.	12–15	"	9	2.1	0.3
GOUV. SARATOW.					
Fabr. d. Gesellsch. Saratowsk. Manufaktur. Kr. Saratow. Glt.	21	360	5	2.0	0.5
Schirokij u. Krutezkij Buerak, Kr. Saratow. Glt.	20	325	2	0.7	0.1
Fl. Sinjaga, Gubernatorowka, Nosarowka u. Mekatnaja, Kr. Saratow, Glt.	14–21	200	12	2.4	0.4
Saranzewo-Baguj, Kr. Saratow, T.	13–16	360	7	2.7	"
Gebiet zwischen Sinenjkie u. Sosnowka, Kr. Saratow u. Kamyschin. T.	14–16	215	"	1.5	0.2
Trubino-Nishnaja Bannowka, Kr. Kamyschin. T.	"	630	27	17.0	2.6
Lapotj-Berg Durman, Kr. Kamyschin. T.	15–17	540	3	1.8	0.3
Fl. Burluk, (n.d. Eisenbahnbrücke), Kr. Kamyschin. T.	15	145	2	0.3	0.05
Fl. Burluk, Umgeg. v. Gretschanaja, Kr. Kamyschin. T.	16	540	3	0.8	0.3
Fl. Medwediza, Melowatka, Kr. Kamyschin. T.	22	"	2	0.9	0.2
			5916.5	1.280	246.1

1. Die Qualität der Phosphorite—der Prozentgehalt an P_2O_5.
2. Die Produktivität, d. h. die Menge der Phosphorite in Kilogr., welche auf 1 quadr. Meter kommt.
3. Die Grösse der von den Phosphoriten eingenommenen Flächen in quadr. Kilom.
4. Die Quantität der Phosphorsäure in Mill. t.-MT.
5. Die Quantität der Phosphorsäure in Mill. t.-MT.

Der Gesamtvorrat der Phosphorite in den bereits untersuchten Gebieten ist 1280 millionen t. Phosphorite verschiedener Qualität, auf einer Fläche von 5916, 5 qkm.

Die durchschnittliche Produktivität beträgt 216 kg. Verteilt man die ganze Phosphoritmenge, entsprechend ihrem Prozentgehalt an P_2O_5, in die drei Gruppen, welche wir für die Übersichtskarte ausschieden, so erhalten wir die folgenden Zahlen:

Phosphorite mit P_2O_5 Gehalt von	Menge der Phosphorite	In Prozenten
12-18%	427 Mill t.	33%
18-24%	715 "	56%
7-24%	138 "	11%

In der fünften Längsreihe der Tabelle ist die Gesamtmenge an P_2O_5 angeführt, welche in den Phosphoriten jedes einzelnen Rayons eingeschlossen ist. Die Gesamtmenge des ganzten P_2O_5 in der Phosphoriten aller genannter Rayons berechnet sich auf 246 Mill. t.

Zieht man in Betracht, dass fast die ganze P_2O_5-Menge in den untersuchten Gebieten als Fluorapatitverbindung auftritt, so lässt sich der gesamte Fluorgehalt mit 20 mill. t. und der Gehalt an Fluorcalcium mit ca. 41 mill t. bestimmen. Diese Zahlen sprechen deutlich genug für die weite Verbreitung des Fluors in sedimentären Gesteinen. Bei den Umwandlungsprozessen, welchen die Phosphorite unter der Einwirkung von chemischen und chemischbiologischen Agenzien in der Erdkruste ausgesetzt sind, können bedeutende Mengen von Fluorcalcium frei werden und sich, als Fluorit, in sedimetären Gesteinen absetzen.

Betrachtet man die Zahlen oder wirft man einen Blick auf die Übersichtskarte, so fällt einem gleich ins Auge, dass im Bereich der untersuchten Gebiete die grüne Farbe die kleinste Fläche einnimmt: Phosphorite mit einem P_2O_5-Gehalt über 24% sind selten.

Auf der untersuchten Fläche des Europäischen Russlands ist folglich die Gesamtmenge der Phosphorsäure gross, aber die *Verteilung ungünstig* nirgends sammelt sie sich in grösseren Mengen zu einer Phosphoritmasse an, welche in genügendem Masse von fremdem Material verschont wäre,—ist vielmehr ärmlich auf einem weiten Areal verstreut.

In dieser Hinsicht halten die beschriebenen Phosphoritlagerstätten einen Vergleich mit den gegenwärtig industriell wichtigsten Phosphoritgegenden Nordamerikas und Nordafrikas ganz und gar nicht aus.

Bedenkt man jedoch, dass die Nachfrage nach phosphorsauren Düngemitteln stetig progressiert und auch weiter progressieren muss, kann man die Zukunft der Phosphorite mit geringerem Gehalt an P_2O_5 doch nicht hoffnungslos nennen.

Die progressierende Intensivität der Agrikultur macht die Frage bezüglich der *Weltvorräte* an Phosphorsäure, welche in den Dienst des Ackerbaus gestellt werden könnten, zur Tagesaufgabe.

Es unterliegt keinem Zweifel, dass die wertvollste und vollkommenste Schätzung dieser Art durch die gemeinsamen Bemühungen der Forscher aller Länder, vereint durch eine internationale Organisation, erzielt werden könnte, wie dieses bereits vom XI Kongress in Stockholm für die Eisenerze und vom gegenwärtigen Kongress für die Steinkohle ausgeführt wurde.

Von diesen Motiven geleitet, wandte ich mich an das Comité des Kongresses mit dem Vorschlag, in die Zahl der Tagesfragen des nächsten XIII Internationalen Geologenkongresses die Organisation einer kollektiven Arbeit aufzunehmen, welche sich die Schätzung der Weltvorräte der Phosphorsäure zur Aufgabe stellen würde.

Die Beantwortung dieser Frage würde es zugleich ermöglichen in weiterem Masstabe sich ein Bild davon zu schaffen, wann die ärmeren Phosphorite an die Reihe kommen müssen, wann die Bedürfnisse des Ackerbaues die Verwertung phosphorsäurearmer Phosphorite notwendig machen wird.

THE OCCURRENCE OF PETROLEUM AND NATURAL GAS IN THE MID-CONTINENT FIELD.

BY

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AREA.

The Mid-Continent oil field, as the term is generally used, includes an area approximately 200 miles long from north to south, and 100 miles wide, located in southeastern Kansas and eastern Oklahoma. The limits of the productive field have not yet been sharply determined, and probably will not be for many years. The most northern point at which oil has been found in quantity is near Paola, Kansas, some 50 miles southwest of Kansas City. The most southern point is near Coalgate, Oklahoma. The southeastern part of the Mid-Continent field extends from Oklahoma into the vicinity of Fort Smith, Arkansas. The westernmost limit, as at present developed, is at Blackwell, Kay County, Oklahoma. The area within which oil and gas have been found in commercial quantities contains approximately 20,000 square miles.

STRATIGRAPHY.

The rocks in which the hydrocarbons occur throughout the two states, consist entirely of sediments of Pennsylvanian age which lie usually unconformably, above the Boone chert, a limestone of Mississippian age. This limestone, popularly known to oil men as "the Mississippi Lime," outcrops in the region east of Grand River, in northeastern Oklahoma and southeastern Kansas. The Pennsylvanian formations, as exposed in the Mid-Continent field, consist of alternating sandstones, shales and limestones with an occasional bed of coal. Throughout northern Oklahoma and Kansas the Pennsylvanian rocks dip west at rather constant slopes, varying from 50 feet to the mile near their eastern exposure, to less than 20 feet to the mile in the western part of the area. In the southern part of the Mid-Continent field the rocks have been folded into a series of anticlines and synclines.

South and west from the region of the exposure of the Boone chert, the Pennsylvanian sediments thicken rapidly, particularly in the basal portion of the series. This fact may be illustrated by comparing the thickness in various parts of the area of the Cherokee shales, the lowermost formation of Pennsylvanian age, which lies below the Fort Scott limestone. In southern Kansas the thickness of the Cherokee shales approximates 150 feet. On passing southward the Pennsylvanian rocks below the Fort Scott limestone thicken gradually until, in the region of McAlester, in east-central Oklahoma, the combined thickness of the Pennsylvanian sediments below the Calvin sandstone, which is the approximate southern equivalent of the Fort Scott limestone, aggregates 10,000 feet.

In southern Kansas a considerable part of the rocks of the Pennsylvanian series is limestone. On passing south into Oklahoma, the various limestones gradually become thinner and many of them disappear, while sandstones become more and more prominent, and shales become relatively thicker. A cross section of the Pennsylvanian series taken 50 miles north of the Kansas line would show that more than one fourth of the thickness of the Pennsylvanian sediments at that place is limestone. A cross section taken at Tulsa, Oklahoma, 60 miles south of the Kansas-Oklahoma line, would demonstrate that, there, not one twentieth of the thickness of the series is limestone.

OCCURRENCE OF PETROLEUM.

Oil Sands.

The petroleum and natural gas found in the Mid-Continent field occur altogether in beds of sandstone which occur interstratified with shales and limestones. In the great majority of cases the stratum lying above the oil-bearing sand, that is to say, the cap rock which holds the oil down, is shale; but in a few instances it is limestone. All the oil sands in the Mid-Continent field are more or less lenticular. Some of the more persistent of the sands, as for instance the Bartlesville sand and the Wayside sand, are believed to occupy an area of several thousand square miles, while others are but a few square miles in area. Even the most persistent of the sands, however, often vary much in thickness, even in short distances.

Pools.

The term "pool" is applied to a small area from which oil or gas has been produced. The size of a pool in the Mid-Continent field varies from a fraction of a square mile to several square miles. For instance, the Flat Rock pool, near Tulsa, Oklahoma, is two miles long and one mile wide. Glenn pool is twelve miles long and five miles wide. Hamilton Switch pool occupies less than a square mile. The size, shape and location of the various pools in different parts of the Mid-Continent field differ materially. At the present time there are more than 80 separate pools and new ones are constantly coming to light.

Location of Sands.

More than three fourths of the oil and gas so far produced in the Mid-Continent field has come from beds of sandstone contained in the Cherokee shales, which, as stated above, occupy the basal portion of the Pennsylvanian series in Oklahoma and Kansas. Many of the oil bearing sands have received local names such as Bartlesville, Tucker, Burgess, Glenn, Tancha, Dutcher, Layton and Cleveland.

It is believed that the oil-bearing sands reach the surface in southeastern Kansas and eastern Oklahoma, in the region about midway between the exposures of the Boone chert and the Fort Scott limestone, where they form a row of timber-covered sandstone hills and ridges. These sandstones disappear to the westward beneath overlying limestones and shales. In the Shallow field, in eastern Nowata county, these sands occur at depths varying from 300 to 800 feet beneath the surface. The local name applied to these sands is usually that of the pool in which they were first encountered, as, Alluwe, Coodys Bluff and Childers Sands. Near Bartlesville and Tulsa they lie at depths varying from 1,200 to 2,000 feet beneath the surface. In the Cleveland pool the same sands are 2,700 feet deep.

Above the horizon of the Fort Scott limestone, which is know to the driller as the "Oswego Lime," there are a number of sands, which, in the western part of the Mid-Continent field, have yielded considerable quantities of oil and gas. In Washington and Osage counties in northern Oklahoma and in Chautauqua and Montgomery counties in southern Kansas, much of the oil has been obtained from two sands known to the driller as the Wayside and the Peru sands, which occur at from 600 to 800 feet beneath the surface in these places. Both of these sands lie above the Fort Scott limestone. The Layton and Cleveland sands found in the Cleveland and Cushing pools are at the approximate horizon of the Peru and Wayside sands. The oil and gas in the Ponca City pool and the gas in the Blackwell pool, both of which lie at a higher geological level than any of the other oil pools in Oklahoma, come from sands still higher in the Pennsylvanian series than the Layton and Cleveland sands. In addition to the sands mentioned above, which are usually quite persistent and are believed to occur in a number of separate pools, there are, in the Mid-Continent field, many so-called "stray sands," that is to say, sands containing oil and gas which seem to have a rather limited areal extent.

Number of Sands.

In many of the pools throughout this region, there is but one producing oil sand, while in others there are several sands. For instance, in the vicinity of the world-famous Glenn pool, which during the past six years has produced 120,000,000 barrels of oil, there are four producing sands, known as the Red Fork sand, which lies at a depth of 1,300 feet, the Glenn sand at 1,500 feet, the Tancha sand at 1,700 feet, and the Dutcher sand at 2,200 feet. In the Bartlesville field there are eight productive oil sands, as follows:

Unnamed sand	at	250 feet.
Unnamed sand	at	400 "
Wayside sand	at	650 "
Peru sand	at	825 "
Oswego sand	at	1,000 "
Squirrel sand	at	1,100 "
Bartlesville sand	at	1,250 "
Burgess sand	at	1,500 "

In some parts of the Bartlesville region as many as four of these sands have been found productive on the same property, and it is a common occurrence for two of them to produce oil. In the Cleveland field there are five producing sands and in the Cushing field five: in the Ponca City field there are seven sands that produce oil or gas in commerical quantities.

Continuity of Sands.

As has been stated above, all the sands in the Mid-Continent field are more or less lenticular, and often thicken and thin rapidly in short distances. Not enough drilling has yet been done throughout the region to demonstrate with certainty the continuity of the various sands. To cite a specific example, most oil men and most geologists who have studied the conditions now believe that the Bartlesville sand, which has produced such immense quantities of oil in northern Oklahoma, extends uninterruptedly from southern Kansas through Washington and Osage counties, Oklahoma, as far as the Bird Creek and Flat Rock fields, near Tulsa. The same sand is also supposed to occur at Cleveland. In other words, the Bartlesville sand is commonly believed to be continuous over more than 5,000 square miles.

In point of fact, however, no one knows with certainty that this is true. It is not possible in the light of present knowledge to either prove or disprove the assertion. No one can be certain that the sand which contains oil or gas at a depth of about 1,100 feet near Independence, Kansas, is the same sand which contains oil at 1,200 feet at Bartlesville, at 1,300 feet in the Flat Rock field, near Tulsa, and at 2,400 feet at Cleveland. Sufficient investigations have been made, however, to demonstrate with approximate certainty that the oil-producing sands in these four widely separated localities, occurring at the depths mentioned, are situated at about the same geological horizon. Taking into account, however, the known lenticular nature of all the Pennsylvanian sands in the region, it is as yet too early to make a definite prediction as to the continuity of this or, in fact, of any other sand in the Mid-Continent field. It is quite possible that further development will show that various lenticular sands appear and disappear throughout this region, and that the Bartlesville sand is by no means continuous.

FACTORS GOVERNING ACCUMULATION.

The two dominant factors which appear to govern the accumulation of petroleum and natural gas in the Mid-Continent field are:

(1) The thickness of the oil sands, and

(2) The structure of the rocks.

Thickness of Sands.

It goes without saying that, other things being equal, the thicker the sand, the more oil will be contained therein. The Glenn pool, one of the most noted in the world, owes its prominence largely to the fact that the Glenn sand averages from 75 to 100 feet in thickness at this place, thus providing an immense reservoir for the storage of petroleum. The Bartlesville sand averages from 50 to 60 feet thick, and scores of millions of barrels of oil have been produced from it. The Cleveland sand, which is also a thick sand, has produced a vast amount of petroleum.

On the other hand, many sands, as for instance the Wayside, Peru, Childers, Alluwe and others, which average 20 to 40 feet in thickness, have produced smaller amounts of oil. Generally speaking, the wells in the thicker sands have initial productions varying from 100 to 1,500 barrels of oil per day and settle after two to three years to 20 to 100 barrels per day. The wells in the thinner sands usually have initial productions of from 30 to 200 barrels per day, and settle to 5 to 20 barrels per day. Thus it will be seen that, other things being equal, it is very much more profitable to operate the thicker sands. It must be remembered, however, that the thinner sands are often comparatively shallow, occurring at depths of from 300 to 1,000 feet, while the thick sands usually lie at depths varying from 1,200 to 3,000 feet beneath the surface.

The usual cost of drilling a well to the shallow sands, where an initial production of 50 barrels a day may be expected, varies from $1,000 to $3,000, while wells 2,200 feet deep in the Cushing field, where the initial production averages 500 barrels per day, cost from $8,000 to $12,000 to drill and equip. It will be understood that in cases where any considerable number of unproductive wells occur in a region of deep sand the operation may be a losing one, but where the wells encounter large amounts of oil, the operation is extremely profitable. The general experience throughout the field has been that operation in the thinner sands in the shallow fields is a far safer investment, while the operation of the deep sands is more speculative, but with the possibility of very much larger profits.

Structure.

A second factor which governs the accumulation of oil in the Mid-Continent field is the structure of the rocks. Throughout the greater part of this region the general structure is that of a broad monocline. The normal dip of the rocks is to the west, decreasing from 50 feet to the mile near the eastern outcrop of the Pennsylvanian series, to 20 or 10 feet to the mile in the western part of the Mid-Continent field. In many places, however, this western dip of the rocks has been interrupted by local folding.

These folds are usually not strongly marked, and in fact are often inconspicuous. In many, perhaps most, cases the folds are in fact nothing but terraces, or "arrested anticlines." That is to say, the rocks in certain localities, instead of having the normal dip to the west, lie nearly level. In comparatively few places throughout the greater part of the field, may well-marked easterly dips be observed.

Careful studies of geological conditions have demonstrated that there is in the Mid-Continent field a rather definite relation between the structure of the rocks and the occurrence of oil and gas. Those who are considered to be the best authorities on the subject do not hesitate to say that, so far as observation goes, practically every oil pool in the Mid-Continent field may be accounted for by structure. It must be admitted, however, that it is not always possible to determine this structure from surface observation, so that a careful study of well records is often necessary to determine it; but, when once understood, the relationships between structure and production are usually obvious.

In the southern part of the area occupied by Pennsylvanian rocks, that is to say, in the region from Muskogee southwest to Atoka, and southeast to Forth Smith, Arkansas, the general westerly dips noticed farther north give way to a series of alternating anticlines and synclines.

There has been no great amount of drilling in this region, and very little petroleum has so far been found therein. It is, however, a very significant fact that, throughout this region, in practically every known case where drilling has been done along anticlinal folds, natural gas has been found. The gas fields near Fort Smith and Manfield, Arkansas, and near Poteau, Spiro, Kinta, Red Oak and Wardville, Oklahoma, are located on or near the axes of well-marked anticlines. Up to the present time not enough drilling has been accomplished, throughout this part of the Mid-Continent field, to demonstrate the absence or presence of oil in quantity. It is altogether probable, however, that extensive operations will reveal the presence of considerable amounts of petroleum.

Relation between Sands and Structure.

Within the developed portion of the Mid-Continent field where, as stated above, the anticlines are not so conspicuous as in the regions just discussed, the largest oil pools almost invariably occur where an unusually thick sand underlies an anticlinal fold, or a terrace. The Bartlesville, Glenn, Cleveland, Cushing, and in fact all the larger pools that have produced unusually large amounts of petroleum, contain this very favorable combination of thick sand and structure. In many instances, however, oil has been found in considerable quantities in regions where there is little or no evidence that the normal western dip of the rocks has been interrupted. Under such conditions, however, the drill reveals the fact that the oil sands are unusually thick. Instances of this kind occur in certain parts of the Bartlesville pool, in the Bird Creek pool, in the Shallow field, and in many of the pools in the Osage Nation

PRODUCTION AND DEVELOPMENT.

The production of petroleum in the Mid-Continent field increased from 74,714 barrels in 1900 to 59,343,850 barrels in 1911.

During the past year there has been more development than ever before in the history of the field. This may be accounted for by the steady advance in the price of petroleum. In 1908 the petroleum in the Mid-Continent field sold for 35 cents per barrel. At the time of this writing, May 1913, the price is 88 cents per barrel, and it will probably increase.

Within the past few months there has been much prospecting in all parts of the Mid-Continent field. The Cushing pool, which bids fair to rival the world-famous Glenn pool, was first opened in March, 1912. Its daily production is now 100,000 barrels. Within the year the known areas of a number of the older pools have been materially extended and a number of new pools have come to light.

A region occupying some five counties in southwestern Oklahoma, which has heretofore remained unexploited, is now attracting much attention. Within the past year a number of wells have been drilled throughout this region, and practically all have produced oil or gas. Geologists who have studied conditions in this part of the state are of the opinion that this field, when developed, may rival the field already developed in the northeastern part of the state.

NATURAL GAS.

The amount of natural gas produced in the Mid-Continent field is very great. At least 90 per cent. of all the oil wells so far drilled contain natural gas. In many cases the wells produce gas only; however, gas and oil usually occur in the same sand. In many cases after the gas in a well has been practically exhausted, oil is produced. To use the drillers parlance, "the well drills itself into oil."

The capacity of gas wells of the Mid-Continent field varies up to 50,000,000 cubic feet per day. Some of the most extensive gas fields so far discovered lie near Iola, Independence and Caney, Kansas, and Copan, Bartlesville and Collinsville, Oklahoma.

A well recently drilled to a depth of less than 700 feet in the new field near Loco, Stephens county, southwestern Oklahoma, is producing 25,000,000 cubic feet of gas per day.

The gas from the Mid-Continent field is utilized both for manufacturing purposes and for domestic use. Gas from this field, supplied the greater part of the cities of Oklahoma and eastern Kansas, and has been piped as far as Joplin, Kansas City and St. Joseph, Missouri. Much of the so-called casing-head gas is now being utilized for the manufacture of gasoline or petrol, there being about twenty-five gasoline plants in operation in the field.

The waste of natural gas in this field has been enormous. Legislation has checked, but has by no means stopped this gigantic waste. At the present time tens of millions of cubic feet of the most valuable fuel is being dissipated into the air each day. Yet for this negligence there seems to be no immediate effective remedy.

At present there is no way of estimating the amount of natural gas now available in the Mid-Continent field, but it is probably between one billion and two billion cubic feet per day.

FUTURE OF MID-CONTINENT FIELD.

There is no means of knowing accurately the possible extent of the Mid-Continent field, but, taking into account all the available data, including the stratigraphy and structure of the rocks, and the known occurrence of oil and gas under existing conditions, it may safely be estimated that, at the present time, not over one fourth of the future available territory in Oklahoma and Kansas has been drilled. New fields are constantly coming to light and the limits of old ones are being extended.

Many of the wells now in operation have been producing oil for fifteen years, and are by no means exhausted. At the present rate of development, it will be many years before the productive area of the fields has been determined. It will be many more years before it all will be drilled. There need be no surprise if the Mid-Continent field is producing both oil and gas one hundred years from this date.

NATURAL GAS IN TRANSYLVANIA.

BY

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In connection with the discussion of the Coal Resources of the World, the recent discovery in Hungary of important quantities of natural gas may prove to be of interest.

Burning gas has long been known in the upper Miocene of Transylvania. JACQUIN in 1808, and later PARTSCH in 1827, gave detailed descriptions of the "burning well" of F. Bajom and Magyar Sáros between the two Küküllö rivers.[1]

It is only the deep boring of recent years, conducted by the Finance Department of Hungary, that has given a proper conception of the great richness in natural gas of Transylvania. It must indeed be mentioned that these deep borings were first made not for gas but for the purpose of finding *kali-salts*, which some Hungarian geologists believe to be associated with the rich, late Tertiary (Miocene) salt deposits.

The first deep boring to discover *kali-salts* was made in the centre of the Tertiary basin of Transylvania in Great-Sármás in 1908. It was discontinued at a depth of 627 metres because of technical difficulties. The little methane mingled with salty water which spouted out of the marly sandstone at a depth of 460-470 metres, and later at 570-580 metres, was given little attention.

As this boring was made in the synclinal portion of the folded Miocene strata, the next boring was made 2.9 kilometres farther toward the northeast in the anticlinal, where it encountered at 22 metres natural gas and iodine-bearing salt water in sandy strata. At 302 metres drilling was stopped by a tremendous flow of natural gas, flowing at the rate of 193 cubic metres per second, that is, 912,124 cubic metres in 24 hours. The temperature of the gas is 4°C.

Later geological investigations, designed by the government to supply detailed information regarding the Tertiary basin, showed that the vault-like anticline of sandy Miocene strata contains natural gas chiefly.[2]

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[1] *Geologie Siebenbürgens*, von FR. RITTER VON HAUER und DR. G. STACHE, Wien, 1863, S. 592, etc.

[2] The results of these studies were published in 1911 in a book, entitled: I. *Az Erdélyi Medence földgázt tartalmazó antiklinálisairól*, by Prof. DR. BÖCKH HÚGÓ. II. *A Nagysármás és Kissármás községek határában végzett mélyfúrások leirása*, by Ing. BÖHM FERENC, and will be republished this year (1913).

The anticlinal axes do not run straight but curve in zig-zag courses that seem to be influenced by the older marginal rocks of the basin.

The gas-bearing strata are curved not only horizontally, but—as can best be verified by the interstratified dacitic tuff beds—exhibit great vertical undulations. In this manner are formed the great gas-bearing vaults that have been mentioned above.

The first boring showed also that strata which lie nearly horizontal at the surface have greater inclinations in depth, for instance, 40° at 490 metres. This condition obtains frequently in the later Miocene beds of Transylvania, as well as in the petroleum fields of Roumania, where it was first observed by Prof. Mrazek and named "diapir fold."

The detailed geological investigations showed also that, on the margin of the Miocene basin the anticlinal folds are much closer together and have much greater inclinations on the surface than towards the middle of the basin, where they are farther apart.

The richest gas-bearing folds have only a slight dip at the surface but become more steeply inclined with depth, as is the case in the district of Sármás.

At the present time ten wells have been bored to study the gas-bearing Sármás dome, which give more than 1.5 million (1,658,434) cubic metres of natural gas per day. These wells show that not only is the country near the anticlinal axis rich in natural gas but also that which lies within one kilometre of the axis.

All the wells are capped and ready for the utilization of the gas.

In connection with the gas field of Sármás must be mentioned the great gas eruption of October 29th, 1911. This occurred near the second well, in a place where previously, within the memory of man, gas mingled with salt water burst out along a line of fracture and was utilized for the treatment of rheumatic diseases, constituting a primitive watering-place. This gas eruption was preceded by slight earthquakes, and when the gas caught fire it burned with high and terrifying flames during the first night, gradually subsiding during the following days, until it was finally extinguished by the militia.

This gas eruption seriously damaged the railway near by and destroyed the simple watering-place. It was also of great interest to geologists, for during our last investigations we found traces of many hundreds of such eruptions, which produced mud volcanoes generally similar to those of the last eruption at Sármás.

On the anticlinal axis of Sármás a second dome forms the gas field of *Mezö Sámsond*, which is now tapped by two wells 365.7 metres and 215.40 metres deep respectively, and giving 83,000 cubic metres and 30,000 cubic metres of gas per day respectively or, together, 113,000 cubic metres. The dome of Mezö Sámsond, as I have proved by tracing the course of one thin dacitic tuff bed, is more compressed than that of Sármás.

The third great dome on this anticlinal line is that of *Mezö Kapus*, which has not yet been examined by deep borings.

The strata, which seem to dip far beneath the surface farther south between the Maros and Little Küküllo river, rise again to a dome in *Magyar Sáros, Bajom and Kis-Kapus* districts. This country has long been known for its burning gas and now contains seven wells, 140, 147, 153, 327, 102, 118 and 147 metres deep, which yield 453,000 cubic metres of gas per day.

Between Mezö Sámsond and Torda is another anticlinal vault which also contains much gas, as indicated by the *Mezö-Záh* well. This well, which is 103.42 metres deep, yields 108,000 cubic metres of gas daily.

Collectively these wells have a potential yield of 2,334,882 cubic metres of gas per day.

To form a proper conception of the richness of these gas fields, one must bear in mind the fact that all these borings were made only for exploration purposes and that the quantity can be augmented both by continuing the borings in depth and by opening new wells.

The gas is also of excellent quality. That of the second well (at Sármás) contains, according to the analysis of Prof. Dr. PFEIFER,

Methane (CH_4)	99.25 per cent.
Nitrogen (N)	0.75 per cent.

According to the same analyst, one litre of the salty water from this well gives 74.3147 grammes of solid residue as follows:

KCl	0.4100 grammes.
NH_4Cl	0.2845 "
Na Cl	64.7553 "
Ca Cl_2	3.8778 "
Ca CO_3	0.1125 "
Mg Cl_2	4.8663 "
NaI	0.0083 "

All these details seem to show that the gas may be associated with petroleum.

The depths, quantities, pressures and chemical components of the separate wells are as follows:[1]

[1] These data, up to June 15th, of this year, I received from Engineer FRANCIS BÖHM, chief of the exploration division of the Finance Department.

TABLE

		Locality	Depth	Flow per day		Pressure		Methane CH_4 %	Heavy hydrocarbs C_nH_{2n} %	Oxygen O %	Nitrogen N %	Calorific value per cbm.	British thermal units
			Metres	Cbm.	Cubic feet	Atm.	Pounds per sq. in.						
1	2	Kis Sármás....	302.	864000	30499200.0	26.5	376.30	99.10	......	0.53	0.37	8489	33616.41
2	10	" ...	68.6	54371	1919296.3	13.3	188.86	99.10	......	0.54	0.36	8489	33616.44
3	11	" ...	86.8	65000	2294500.0	12.	170.4	98.94	......	0.83	0.23	8471	33545.16
4	12	" ...	226.2	204063	7203233.9	25.	355.0	98.74	......	1.18	0.18	8454	33476.64
5	13	" ...	108.0	70000	2471000.0	8.2	116.44	97.90	1.50	0.60	....	8591	34020.36
6	14	Bázna........	140.6	55000	1941500.0	21.5	305.30	98.90	0.40	0.70	....	8524	33755.04
7	15	Mezö Sámsond	265.7	83000	2929000.0	36.9	523.98	....	......	....	....	....	....
8	16	" ...	215.40	30000	1059000.0	18.25	259.15	....	......	....	....	....	....
9	17	Bázna........	147.6	38000	1341400.0	16.7	237.14	....	......	....	....	....	....
10	18	Magyar Sáros..	153.8	196000	6918800.0	19.	269.8	....	......	....	....	....	....
11	19	" ...	327.73	40000	1412000.0	....	......	98.90	0.60	0.50	....	8551	33771.96
12	20	Kis Sármás...	129.00	169000	5965700.0	14.	198.8	....	......	....	....	....	
13	21	" ...	220.39	56000	1976800.0	20.2	286.84	97.90	0.81	0.79	....	....	
14	22	Semmert......	102.0	18000	635400.0	13.5	191.70	....	......	....	....	....	..
15	23	Kis Sármás...	204.3	140000	4942000.0	27.6	391.92	....	......	....	....	....	
16	24	" ...	307.50	36000	1270800.0	17.	241.4	....	......	....	....	....	..
17	25	Kis Kapus....	118.50	86000	3035800.0	17.8	252.76	....	......	....	....		
18	26	Bázna........	147.30	20000	706000.0	16.	227.2	....	......	....	....		
19	27	Kis Sármás...	586.8	......	....	....	......	....	......	....	....	...	
20	29	Mezö Záh.....	103.42	108000	3812400.0	15.8	224.36	....	......	....	....		

Taking into consideration the fact that the heat of one cubic metre of gas is equivalent to the heat of 1.23 kilogrammes of coal with a calorific value of 7000, a day's production of gas (2,334,882 cubic metres) is equivalent to 28,700 tons of coal.

When these operations were first undertaken the Hungarian government expropriated the natural gas as well as the oil in order to prevent selfish speculations.

MODE OF OCCURRENCE AND FORMATION OF NATURAL GAS

To understand the occurrence and possible mode of formation of the natural gas, it is necessary to discuss briefly the geological composition and structure of Transylvania, *i.e.*, of the eastern part of the Carpathian arch.

The terrain of Transylvania may be divided into two parts: (1) the surrounding mountainous older marginal part, and (2) the interior hilly Tertiary basin.

The surrounding margin is composed chiefly of crystalline schists, some Carboniferous (uncertain) strata and red sandstones probably of Permian age, and a nearly complete series of Mesozoic deposits.

In view of the discordant relationships of the probably Permian and Mesozoic, they must be regarded partly as vestiges of the Variscian mountains. The crystalline schists were formed probably from Paleozoic strata by the Hercynian folding, in connection with the eruption of the older granites of Gyalú, etc.). Prof. MURGOCI lectured on the great overfolding in the south Carpathians at our last meeting in Stockholm and tried to connect this overfolding with the overfoldings of the High Tátra as described by the late Prof. UHLIG. Considering the numerous divergent opinions upon the question of the overfolding of the Tátra, we are by no means certain that the overfolding of the border mountains of Transylvania is established in detail, all the less because there are also overfoldings in the western border mountains of Transylvania.

Besides the sediments, Triassic or Jurassic (ante-Tithonic) eruptives (chiefly porphyries, porphyrites and diabases) are found in the bordering mountains of Transylvania, mostly to the right of Maros river.

Another period of great eruptive activity began in the mountains on the western border in Upper Cretaceous time. This brought up chiefly intrusive rocks; granites, grano-diorites (which I call daco-granites, because of the great likeness to dacite), also the rocks to which STACHE first applied the name dacite, and lesser amounts of diorites. I have also described many rhyolites from the mountains of the western border and some andesites. Some fragments of these eruptives are to be found in the late Cretaceous sediments.

It must also be mentioned, that later Miocene eruptives (chiefly andesites and rhyolites) occur in the mountains of the western border. These are important, owing to the deposits of precious metals (gold of Verespatak, etc.) which are associated with them.

The basin is filled, partly with older, partly with later Tertiary deposits. The early Tertiary (Eocene and Oligocene) deposits are more largely developed chiefly near the western margin where, it seems, important late Cretaceous eruptives strengthened the earth's crust. In most cases they are scarcely disturbed and they have a tabular structure, except locally along the margins (Marótlaka Hodosfalva) where they meet the early Cretaceous eruptives.

At other parts of the border very few of the older Tertiary deposits remain: some nummulitic strata on the north near Radna, some on the south border near Poresesd and also a small amount to the east of Lövéte in the Hargita.

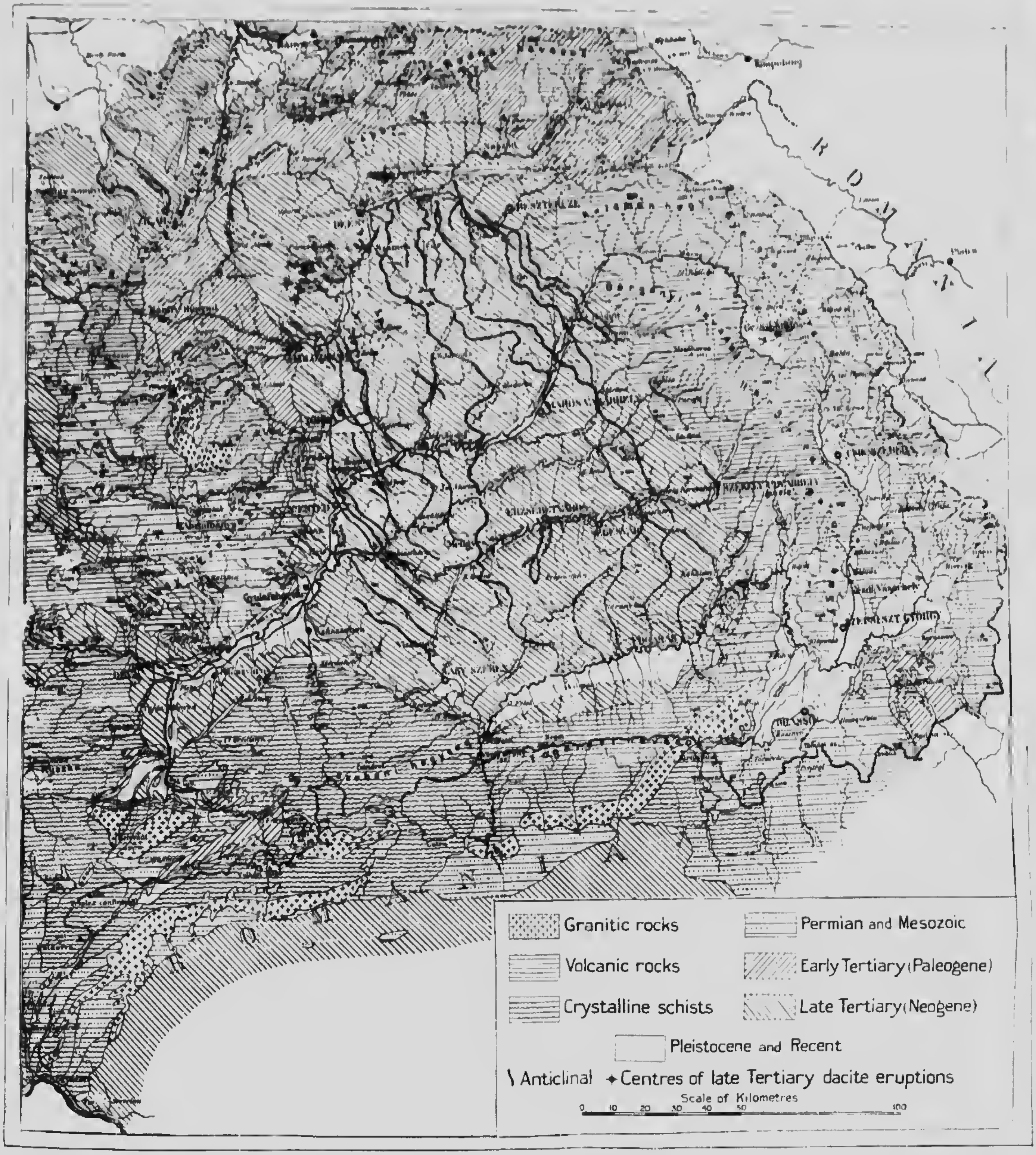
The gas-bearing marly and sandy early Tertiary (Neogen) occupies the central and south-eastern part of the basin. There are important intercalated salt layers representing deposition in a closed basin under dry tropical conditions.

Besides a few scattered plants, remains of fishes and a few shells, these strata contain only great numbers of *Globigerina* which seem, in the absence of other animal life in the salty water, to have existed in immense numbers. Assuming an organic origin for the gas, as I do, we can only accept these foraminifers in explanation.

If we do not accept the organic origin of gas and oil, traces of which latter exists in some outcrops of salt, there is support for a volcanic origin in the dacite eruptions, which, as explosive volcanoes, strewed important tuff beds between the Miocene sediments, chiefly in the western part of the basin. I located some centres of these explosive dacite eruptions on the margin of the Miocene sea, which are marked on the accompanying sketch map.

This volcanic activity continued in the Pliocene period as the great and mostly explosive andesitic eruptions of the Hargita chain. These eruptions give rise in the present post-volcanic time to many hundreds of carbonic-acid fountains in this chain and, less frequently, to solfataric activity. Some minor basalt eruptions on the Olt river seem to have continued until Pleistocene time.

In a brief review of the geological history of Transylvania it is exactly this eruptive activity which holds our attention most. Not only were there important eruptions in (presumably) late Palæozoic (Hercynian) and late Cretaceous periods, and in early Tertiary and late Tertiary, but a long series of eruptive rocks were also formed during the elsewhere quiet Mesozoic era. The greatest of all the volcanic activities was that of late Cretaceous and Tertiary time. This activity, during the Tertiary period, seems to have moved southeast, in relation with later crustal movements such as the breaking up of the Ægean in Pleistocene time.



ROUMANIA
Granitic rocks
Permian and Mesozoic
Volcanic rocks
Early Tertiary (Paleogene)
Crystalline schists
Late Tertiary (Neogene)
Pleistocene and Recent
\ Anticlinal
✦ Centres of late Tertiary dacite eruptions
Scale of Kilometres
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A PHYSICO-CHEMICAL CONTRIBUTION TO THE STUDY OF DOLOMITIZATION.

BY

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Apart from the epoch-making work of VAN'T HOFF on the Stassfurt deposits, the applications of the principles of physical chemistry to geological problems have been made mainly in the study of the crystallization of rock magmas. There will undoubtedly follow an extension of the same mode of treatment to sedimentary processes in general, and to colloidal precipitates and solid diffusions in particular. In the present paper the writer has attempted rather to represent this attitude with reference to the problem of the crystallization of the carbonates of lime and magnesia from saturated sea-water, than to supply definite experimental data on this subject. For this reason the figures incorporated in the text are to be looked upon as abbreviations of broad statements of fact, and not as diagrams quantitatively accurate in detail.

A recent investigation by the writer of the mottling of certain Ordovician limestones in Manitoba[1] has raised for him some points of interest in relation to the much discussed question of dolomitization. The limestones are characterized by irregular markings of a dark brown or slightly bluish colour, which represent recrystallized areas with a much higher magnesia content than that of the grey setting in which they occur. In all probability the dolomitization took place while the calcareous ooze was still hardening, and is not to be ascribed to magnesia-bearing waters affecting the transformation as they percolated downwards through already hardened limestones. The Mg salts were derived most probably from decomposing algæ which became buried in ooze gradually accumulating at the bottom of a quiet sea of only moderate depth. The increase of Mg ions in the waters which permeated the ooze in the immediate vicinity of the algæ would give rise to a purely local mineral transformation. The deeper colour in the dolomitized areas is due to the presence of hematite and limonite, which are to be ascribed to the same source as the salts of magnesium.

Two facts arising out of this investigation should be emphasized. The first is that the mineral transformation took place under conditions of temperature and pressure which effected no recrystallization in the surrounding limestone—and in this connection it must be borne in mind that the process

[1] Jour. Geol., Vol. XXI, No. 5. 1913, p. 402.

did not take place at the surface of the sea. The second is that, although microscopic examination proves the darker material to be composed of homogeneous crystals which react for dolomite optically and with Lemberg's solution, the proportion of $MgCO_3$ to $CaCO_3$ was found by analysis to be less than 1 : 3 ($MgCO_3$ 23.35%. $CaCO_3$, 71.03%). In the voluminous literature which has grown up round the question of dolomitization these two points may be found explicitly or implicitly referred to, but a fuller insistence on their meaning may lead to a clearer conception of the fundamentals of the problem.

THE CONDITIONS OF STABILITY OF CALCITE AND DOLOMITE.

A concise formulation of the probable process of dolomitization is that recently suggested by LINCK in his article on the formation of carbonates in the first volume of DOELTER'S "*Handbuch der Mineralchemie.*" The statement is as follows: "Der Dolomit bildet sich bei Gegenwart von Calciumcarbonat in der Losung oder bei Gegenwart von labilen Modificationen des Calciumcarbonats in Bodenkörper als Produkt eines Gleichgewichts zwischen Magnesiumcarbonat in der Losung und im Bodenkörper unter gleichzeitiger Aufzehrung des vorhandenen Calciumcarbonats." LINCK seems to consider that though $CaCO_3$ is not stable in the presence of dolomite, $MgCO_3$ may be present as a stable solid phase when the dolomite is in process of formation. He suggests that, in cases where a small quantity of $MgCO_3$ is present in a limestone, the dolomitization may be due to the dissolving of $CaCO_3$ and recrystallization of the remainder into dolomite. SKEATS[1] shares this opinion with reference to the dolomitization of calcareous algæ. On the other hand, the view may be advanced, as was done in the instance of local dolomitization referred to above, that the Mg salts present in the algæ go into solution until the concentration of Mg ions in the solution is sufficiently great to cause precipitation of the double salt. For purposes of simplicity we shall at first leave out of consideration the possibility—indicated above—of the formation of mixed crystals between $CaCO_3$, $MgCO_3$, and $CaCO_3MgCO_3$, and shall assume that these three salts are completely immiscible in the solid state.

It is evident that, under the same conditions of temperature, dolomite—or at any rate, limestones with high percentages of Mg—may form in one place and ordinary limestone in another. The concentration of Mg ions in the solution is evidently the determining factor in certain instances of dolomitization. This is undoubtedly the case for the limestones investigated in Manitoba. It will serve our purpose then, in investigating the dolomitization process, to deal mainly with constant temperature and pressure, and to consider the effect of different concentrations of Mg ions in the liquid phase.

$CaCO_3$ in the form of calcite is stable in presence of sea-water of normal composition under low or moderate pressure, and even in presence of a saturated solution of calcium carbonate in water. Dolomite is stable in presence of seawater with a fairly high Mg percentage. The stability seems

[1] Bull. Museum Comp. Zoölogy (Harvard), Vol. XLII, p. 53.

to be most marked in the presence of ammonium salts, particularly ammonium sulphide. But experiments carried out by PFAFF[1] show that dolomite may be obtained from solutions containing $CaCO_3$, $MgCO_3$, and NaCl. We may then consider that in sea-waters of normal temperatures and at moderate depths the stability of calcite or dolomite depends mainly on the concentration of Mg salts. With regard to magnesite, the difficulties encountered in obtaining the mineral experimentally render its stability limits a matter of

FIG. 1.

speculation. At ordinary temperatures and pressures, salts with water of crystallization are obtained; under pressure of CO_2, more frequently at high temperatures and in presence of NaCl, the solid phase has been found to be magnesite. Some natural occurrences, such as the Hall magnesites of the Tyrol, point to the probability that magnesite has been formed at comparatively low temperature by the interaction of highly concentrated Mg salts with dolomite; but the mineral unquestionably owes its origin in the majority of cases to metamorphic processes.

Incorporating in a diagram the above facts on the stability of the minerals with which we are concerned, and taking the vertical and horizontal lines as representing concentrations of Ca and Mg ions, respectively, in a normal sea-water from which the Ca and Mg ions have been removed, we obtain a figure of the general type represented by Fig. 1. The vertical line represents a sea-water with no Mg ions, but a regularly increasing amount of Ca ions from O (where no Ca ions are present) to X, where the Ca ions are in equilibrium with calcite as solid phase for that particular temperature and pressure. Similarly the horizontal line represents a sea-water with no Ca ions, but an increasing amount of Mg ions from O to Y. Between these lines all variations in the concentration of Mg and Ca in the sea-water may be represented. We are concerned here particularly with the relationship between calcite and dolomite; and the conditions of stability of these solid phases are represented at normal temerature and moderate pressure by XP and PQ, respectively. There is no attempt at quantitative accuracy, but the *final* conditions of equilibrium must be somewhat as indicated. The solubility of $CaCO_3$ is probably not lowered by $MgCO_3$ when NaCl is present.[2] On the other hand, unstable phases of $CaCO_3$—particularly aragonite—may

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[1] Neues Jahrb. fur Min., Beil. Bd. IX, 1894, p. 485.
[2] HOFMEISTER, Journ. Prakt. Geol., 176.

form.[1] The solubility curve for aragonite lies, however, above that for calcite; and under conditions of maximum stability calcite is the solid phase, even in presence of a certain amount of Mg. The stability of calcite in normal sea-water at ordinary temperatures and moderate depths indicates that the point of intersection of the two equilibrium curves lies between the bisector of the angle XOY and OY, seeing that the proportion of Mg to Ca in normal sea-water is roughly 3 : 1. The actual position of the intersection of the two curves is undoubtedly considerably affected not only by temperature and pressure but also by the character of the sea-water.[2] The nature of the curve PQ in its extension towards the OY axis, and of its intersection with equilibrium curves for Mg salts, need not be considered here.

THREE DOLOMITIZATION PROCESSES.

With the aid of the diagram, three dolomitization processes may be considered: (1) dolomitization of the type suggested in the paper on the Manitoba limestones, where the process is supposed to be due to magnesian salts liberated from algæ; (2) dolomitization due to evaporation and concentration of the waters of inland seas; (3) dolomitization due to percolation of Mg-bearing waters through limestones (subsequent dolomitization). It is not to be understood that these three typical cases are meant to embrace all dolomitization processes. For instance, many cases of dolomitization

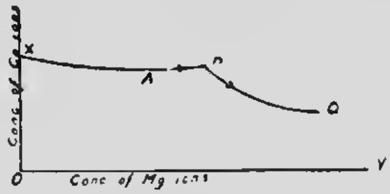

FIG. 2.

may be due to the leaching of calcium carbonate out of elevated limestones by presumably acid meteoric waters. This process is specially emphasized by CLARKE.[3] Here we are dealing only with the final product of equilibrium between a normal or concentrated sea-water and the solid phase. Such equilibrium conditions can only be established after long continued contact between solid and liquid phases, owing to the relative insolubility of calcite and dolomite.

Case I. Here the concentration of the sea-water, before solution of Mg salts takes place, is represented by the point A (Fig. 2). Calcite as a solid phase is stable in presence of this solution. $MgCO_3$ or other Mg salts, however, are unstable and *will gradually go into solution*, the composition of the solution moving along A to P. The stable phases are now calcite and dolomite, and a certain amount of dolomite will be precipitated. If evapora-

[1] LINCK, Jenaisch. Zeitschr. f. Naturw., 1909, p. 267.
[2] See PFAFF's Experiments, loc. cit.
[3] Data of Geochemistry, p. 541.

tion and concentration does not take place, the amount of dolomite precipitated will be small, and the composition of the solution will remain constantly that represented by the point P. With a larger amount of Mg salt to go

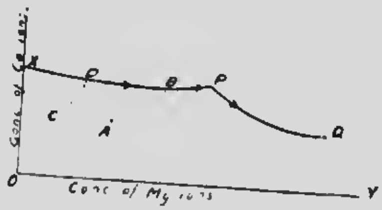

FIG. 3

into solution or with slight concentration, calcite becomes unstable and goes into solution, more dolomite is formed, and the composition of the solution may move from P towards Q. It is to be noted then that if $MgCO_3$ be present in small amount in calcareous algæ in a sea-water represented by A, dolomitization would take place, not by the dissolving of the excess of $CaCO_3$, but by the dissolving of $MgCO_3$ and precipitation of the double salt out of solution. The only way in which dolomite can be conceived to have formed is as a precipitate out of a solution saturated for salt.

Case II. In the case of an inland basin exposed to solar concentration, the initial stage may be represented by a solution of composition A (Fig. 3), which has not yet reached equilibrium with the calcite which has been deposited by organic agency; or, it may be, by a solution of composition C with no solid phase in contact with it. On being concentrated, the solution

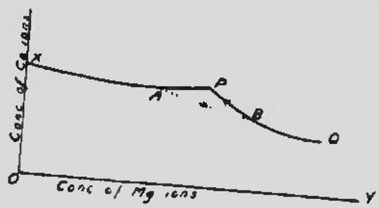

FIG 4.

changes in composition along the line AB (or CD); continuous precipitation of calcite now ensues, until the water is represented in composition by P, when dolomite also forms. With continued evaporation, dolomite continues to form, calcite becomes unstable and passes into solution, and the composition of the solution may move from P towards Q.

Case III. In this case Mg-bearing waters descend (or ascend) into limestones which are in contact with relatively small quantities of underground water, and where the stable solid phase is calcite, for which the water is saturated. The composition of the underground water may be represented by A (Fig. 4). With the introduction of the meteoric (or abysmal) water, the composition of the solution will suddenly change to some point B, where dolomite is the stable phase. Calcite will go into solution, and dolomite will form. If calcite continues to dissolve, the concentration of the solution will gradually change to P, where calcite and dolomite are both stable.

In none of the cases considered, does dolomitization take place by the dissolving of excess of $CaCO_3$, and consequent increase in relative proportions of $MgCO_3$ present in the solid state. Reasoning based on the law of mass action[1] must be somewhat modified by the consideration of the solubilities of the solid phases possible. If the premises on which the deductions are based be granted, the conclusions are of some importance in connection with dolomitization in general, and with the transformation of calcareous algæ in particular. The diagrams also explain why a slight increase of Mg ions may lead to a very considerable amount of dolomitization. Whether the inference that both dolomite and calcite may, in certain instances, occur as stable phases can be held to explain the occurrence of magnesian limestones, is a matter that will be discussed later.

ISOMORPHISM OF CALCITE, DOLOMITE, AND MAGNESITE.

The foregoing is based on the assumption that calcite, dolomite, and magnesite do not form mixed crystals. We must now enquire more closely into the relationships, isomorphous or otherwise, of the three minerals; a lack of precision on this point has led in the past to a certain amount of haziness in the formulation of dolomitization processes. RETGER's classical work on the three minerals[2] was mainly concerned with specific gravity values, from which he concluded that dolomite was not a member of an isomorphous series of which calcite and magnesite would be the end members, but an isolated compound. He also considered calcite and magnesite to be practically immiscible. His conclusions seemed amply substantiated by the discovery that dolomite crystallizes in a less symmetrical class of the

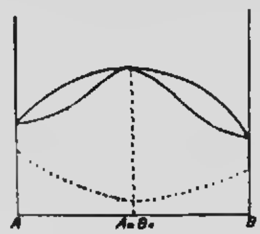

FIG. 5.

hexagonal system than calcite and magnesite, and by the large number of analyses of the three minerals that show only very small amounts of impurities. The result has been that analyses showing both $CaCO_3$ and $MgCO_3$ have been thrown aside as representing mechanical mixtures of two minerals.

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[1] VAN HISE, A Treatise on Metamorphism, pp. 805, 806.
[2] Zeitschr. f. phys. Chem., Bd. VI, p. 230.

The advances made in the study of isomorphous relationships during the last decade have been such that the evidence of specific gravity values alone would not now be taken as conclusive. Besides, the rigid application of Retger's law of the direct proportionality of specific gravity to molecular weight, in the case of an isomorphous series, is hardly justifiable.[1] It assumes that the two components of the mixed crystal occupy each the same volume in the isomorphous mixture that they would occupy as independant crystals. In the case of Type III of ROOZEBOOM (Fig. 5) it may happen that m and n are simple integers (e.g., $m=n=1$). In such a case A_mB_n may be taken as a true compound in the isomorphous series, with a constant melting-temperature like other compounds. It is not unreasonable to suppose that the formation of a compound A B would take place with contraction owing to the simple stoichiometric relations between the two similar compounds A and B. The specific gravity curve might here be represented as the dotted curve in the figure; and Retger's reasoning with regard to the relationship of dolomite to calcite and magnesite would not hold. It is impossible to apply the ordinary methods of thermal analysis to the problem at issue owing to the instability of the compounds at higher temperatures; even under pressure of an atmosphere of CO_2, fusion is a matter of difficulty. We are of necessity thrown back on independent considerations.

The considerable difference in the molecular volumes of the three salts has been frequently pointed out. This is due to the much closer packing of the atoms in the molecule of $MgCO_3$ than in the others, as shown by the fact that the mineral of least molecular weight has the greatest specific gravity; but the gradation in molecular volume is constant in direction, and is not more considerable in magnitude than in the case of the simple sulphates K_2SO, Rb_2SO, Cs_2SO, which TUTTON[2] has shown to be a true isomorphous series. The changes in rhombohedral angle and in topic parameters are such as would support the theory of complete isomorphism. Against this must be placed the fact that Ca salts occasionally stand rather apart in crystallographic properties from the salts of other elements that are closely related chemically, and the further fact, already referred to, that the symmetry of dolomite is lower than that of calcite and magnesite. The lowering of symmetry may be accounted for by the lowering of symmetry of the actual structure of the molecule.[3] The subject of continuous isomorphous mixtures has not yet been gone into sufficiently fully from the crystallographic standpoint, but it is not improbable that when work is directed to this specific problem, it will be found that the mixed crystals of comparatively simple substances, while showing continuous gradation in molecular volume, angles, and topic parameters, possess a lower symmetry

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[1] WALLERANT. Fortschritte d. Mineralogie, Krystallographie u. Petrographie, B. II, 1912, p. 86.
Cf. also DAY and ALLEN: The isomorphism and thermal properties of the felspars, p. 73.

[2] Crystalline Structure and Chemical Constitution, p. 85.

[3] BECKE. Tsch. Min. Petr. Mitt., Bd. II, 1890, p. 257.

than the simpler components, owing to a less symmetrical structure of the complex molecule or of the interlocking point systems.

Considering all the facts, we feel justified in taking calcite, dolomite and magnesite to be an isomorphous series, though not a eutropic group in the sense of the word understood by LINCK. With regard to the possibility of mixed crystals between the various compounds, experimental work furnishes as yet somewhat contradictory evidence. LINCK considers that calcite crystals with small percentages of $MgCO_3$, and dolomite crystals with slightly too large percentages of $CaCO_3$ represent "solid solutions" and not true mixed crystals; and that dolomitic limestones are either mixtures of dolomite and calcite or regular intergrowths of both minerals. LINCK and his pupils have found a true isomorphous series only in the form of the third (vaterite) modification of $CaCo_3$, with the corresponding $MgCO_3$ modification, and with intermediate mixtures. These occur in spherulites which have no counterpart in nature, and which seem on rise of temperature to go over into calcite, dolomite and magnesite[1]. On the other hand, PFAFF[2] obtained homogeneous rhombohedra which gave on analysis percentages varying from 6.93 to 12.77 $CaCO_3$, as impurities in a magnesite, and in another case a fine powder consisting of 66.76 per cent. MgCO and 26.48 per cent. $CaCO_3$. It is of interest to note also in this connection that the

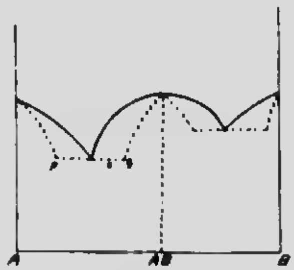

FIG 6.

proportion in which $FeCO_3$ occurs in dolomite (in the mineral usually known as ankerite) is variable, and that it occurs replacing the $MgCO_3$ of the dolomite. In any discussion on this subject, however, particular weight must be laid on the conclusion arrived at by GOSSNER[3] as a result of his investigations, viz., that only those members of an isomorphous series are widely miscible with each other which possess molecular volumes of closely comparable magnitudes.

The most probable interpretation, in the opinion of the writer, of the evidence that has accumulated is that which would be represented diagrammatically by Fig. 6, if the carbonates could be subjected to thermal analysis. $CaCO_3$ (A) takes up a limited amount of $MgCO_3$ (B) in isomor-

[1] DOELTER'S Handbuch der Mineralchemie, Bd. I, p. 125.
[2] Loc. cit.
[3] Zeitschr. f. Kryst. usw., Bd. XLIII, 1907, p. 130.

phous mixture; $MgCO_3$ a limited amount of $CaCO_3$; and $CaCO_3.MgCO_3$ (AB)—a true compound—a limited amount of either. In each case the limits of miscibility are in all likelihood narrow. Outside these limits aggregates are formed. For instance, a carbonate of the composition x represents presumably aggregates of p and q, that is, calcite and dolomite, with in each case the limiting amount of isomorphous admixture. The results of the study of two component systems by the aid of the methods of thermal analysis have amply demonstrated that miscibility—limited or complete—is the rule and not the exception among isomorphous substances.

The diagrams discussed on the assumption that the three minerals are completely immiscible would be somewhat modified if miscibility is possible.[1] If the miscibility is limited in extent, the main features of the discussion remain unchanged. The order of precipitation would remain as explained under the different cases, but instead of the minerals calcite and dolomite, the solid phases would represent minerals varying in composition from A to p and from AB to q respectively. We do not yet know how such mixed crystals would react under the tests used to distinguish calcite and dolomite. Again, the solubility of the components in the mixed crystal may be somewhat different from that of the isolated components.[2] For instance, in a crystal of composition x it is possible, though not highly probable, that the $CaCO_3$ may dissolve more readily than the $MgCO_3$, and that the composition of the crystal may consequently approach more closely that of dolomite. In this way dolomitization could proceed as Linck considers that it actually does take place.

It is of importance in connection with the problem of the process of dolomitization, that the limiting values x and y be determined, and that the solubility of these mixed crystals be ascertained under conditions that resemble as closely as possible those obtaining in nature. An experimental study of this aspect of the question is necessary, and such an investigation is now under consideration.

SUMMARY.

The following are the main conclusions:

1. Dolomitization processes must be considered in the light of the relationship existing between the minerals calcite, dolomite, and magnesite. In order to simplify the discussion, these minerals are first supposed to be completely immiscible.

2. On this basis three typical dolomitization processes are discussed. In each case calcite is primarily the stable solid phase, and is precipitated until the concentration of Mg ions in the solution is sufficiently great to give rise to the precipitation of dolomite. Calcite may then go into solution. In other words, dolomitization is due to the precipitation of dolomite out of solution, and to the dissolving of calcite originally present as solid phase.

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[1] See BANCROFT's Phase Rule, p. 203.

[2] MUTHMANN u. KUNTZE: Zeitschr. f. Kryst. usw., Vol. XXIII, 1894, p. 368.

Magnesian limestones are to be considered as mixtures of calcite and dolomite.

3. Calcite, dolomite, and magnesite form an isomorphous series, but are not so closely related as to constitute a eutropic group.

4. In all probability calcite is miscible, to a limited extent, with dolomite, and dolomite with magnesite. It is not considered that the miscibility is so considerable that the conclusions arrived at from the study of the diagrams would be materially affected.

SOME NOTES ON ROCK ANALYSIS[1]

BY

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This paper on rock analysis is presented to the International Geological Congress with the hope that the results contained therein, which have been derived from an experience of ten years in this work, will have some interest for chemists and for geologists who apply chemistry in their researches.

I propose to consider in this paper:

1. A number of points affecting the accuracy of some of the ordinary determinations in rock analysis, and also certain precautions of recognized merit, for the guidance of the chemist.

2. The total or aggregate percentage obtained in analysis, and its possible usefulness in establishing the accuracy of the methods and manipulations employed, and the applicability of these methods to rocks of varied composition.

1. POINTS AFFECTING THE ACCURACY OF ORDINARY DETERMINATIONS OF ROCK ANALYSIS.

The methods employed by the chemists of the United States Geological Survey have become the standard for workers in this country, and it is these methods which are here considered. Using the general order observed in analysis, I have grouped my remarks upon these methods as follows:

Fusion.—In case sulphides are present, it is necessary to roast the ground sample in the crucible before fusing it with sodium carbonate for the general analysis. This roasting prevents iron alloying with the platinum crucible. The possibility of overlooking sulphides by mere inspection of the sample should be borne in mind.

Silica.—1. Determination of the true percentage of silica in a rock is affected by the grinding of samples in agate mortars. In consequence of having worked on corundum samples, I believe I was the first to point out that silica might be added to the sample by grinding. This was shown by noting the loss in weight of the agate mortar and pestle caused by the abrasion of the sample powder. Further experiments showed that about .3 per cent. of silica is introduced in this way into ordinary rock (silicate) samples. This consideration is of special importance in mineral analysis at least.

[1]Published with the permission of the Director of the Mines Branch.

2. In evaporating the acid solution in platinum dishes for the separation of silica, at times from .1 to .2 per cent. of silica was found to adhere persistently to the surface of the dish. This possibility should not be wholly disregarded.

Iron and alumina oxides.—Even when the ordinary precautions are taken, the ignited precipitate of iron and alumina oxides is liable to be low in weight, especially when large quantities of ferric oxide are present. I have obtained good results by separating the filter paper as usual and moistening the dried precipitate thoroughly with an alcoholic solution of ammonium nitrate, when, after further quick drying, the precipitate is slowly ignited.

Lime.—The simple operation of redissolving the calcium oxalate precipitate derived from the filtrate containing ammonium sulphide should not offer difficulty and is advantageous. The sulphur precipitated at the same time as the calcium oxalate has been found to hinder ready re-solution of the latter. It is, accordingly, safer to ignite this precipitate previous to solution, when all the lime is easily dissolved. This almost superfluous precaution is given also to emphasize the care necessary in performing minor operations.

Determination of iron by H_2S method.—It was formerly the practice to have considerable free sulphuric acid in the sulphate solution of the iron and alumina oxides when H_2S gas was passed through it to reduce the ferric sulphate. I found it difficult to obtain complete reduction by this method, although every precaution was taken. Knowing that some reduction processes, e.g., titanium by zinc in acid solution, are best accomplished when the solution becomes nearly neutral, I successfully applied the same principle in the reduction of iron as follows:

Excess of ammonia was added to the sulphuric acid solution of the iron and alumina oxides, and after neutralizing with sulphuric acid, about 2 c.c. of dilute sulphuric acid were added in excess. In this way the iron was speedily and completely reduced. This method, which I have employed since 1901, has been corroborated by experiments. (*See* Bulletin No. 422 U.S. Geological Survey).

Magnesia.—The following experiments were undertaken to determine the efficiency of adding nitric acid to the ignited magnesium pyrophosphate ($Mg_2P_2O_7$), for the purpose of burning any remaining carbon particles, and obtaining an ignited precipitate in accordance with the formula $Mg_2P_2O_7$:

From a solution of magnesium made up to one litre four equal portions were taken, and the magnesia in each was precipitated twice and washed (as ammonium magnesium phosphate) with the usual precautions. The four precipitates were designated A, B, C, D.

A and B were dried until incipient browning of the filter paper occurred after which the precipitates were separated from the paper, and ignited after the usual manner. A and B were then found to weigh 77.3 and 77.5 milligrammes, as $Mg_2P_2O_7$. Nitric acid was added to the ignited $Mg_2P_2O_7$ in the porcelain crucible, and on evaporation the residue was again ignited and weighed. The gradual loss in weight of the $Mg_2P_2O_7$ is shown by the figures given below, which were obtained by successive repetitions of the process. Further tests are now being made to determine the limit to which this loss will proceed.

Having concluded from the successively diminishing results yielded by A and B that the pyrophosphate cannot be ignited with safety after evaporation with excess of nitric acid, C and D were used to determine magnesia by direct solution of the ammonium magnesium phosphate from the filter, the filtrate being received in a weighed platinum crucible. The filtrate obtained was made alkaline with ammonia, and then very slightly acidified with dilute nitric acid. The solution thus obtained was evaporated to dryness and placed in the air oven over night at 110° C. It was then very easily made ready for weighing by careful volatilization of ammonia salt over a Meker burner; a red heat sufficed to give constant weight, as shown by the later use of a blast and re-weighing. In this way there were obtained 77.1 and 77.4 milligrammes of $Mg_2P_2O_7$ (shown in the table below) as compared with 77.3 and 77.5 milligrammes obtained from A and B in the usual way, without nitric acid treatment. This latter method for C and D (direct solution from the filter paper), is accomplished quickly, and by drying over night, decreases the manipulation usually required for magnesia precipitates.

Treatment of Precipitates.	Crucible Contents as $Mg_2P_2O_7$, in Milligrammes. A	B	Treatment of Precipitates.	Crucible Contents as $Mg_2P_2O_7$, in Milligrammes. C	D
1. Usual ignition only; no acid used.	77.3	77.5	Direct solution from filter in dilute nitric acid, ammonia added in excess, and then dilute nitric acid added in slight excess. Solution then evaporated and dried over night at 110° C., followed by ignition for five minutes over Meker burner.		
2. About 2 c.c. strong nitric acid added to crucible contents of 1, evaporated and ignited.	75.8	70.9			
3. Ditto to crucible contents of 2.	74.3	69.5			
4. Ditto to crucible contents of 3.	72.3	65.9			
5. 5 c.c. of dil. nitric acid added to crucible contents of 4, and then evaporated and ignited.	58.5	43.5		77.1	77.4
6. Ditto to crucible contents of 5.	51.5	35.0			

It may be noted that the first results obtained are practically the same for A, B, C and D, but that, after six repetitions A lost 25.8 milligrammes, and B 42.5 milligrammes, in weight.

Phosphoric anhydride.—In the determination of phosphoric acid by the molybdate method I have found it important to make a double separation of silica from the solution, by dissolving the sodium carbonate fusion in acid. This alteration of the usual process favours a speedier and cleaner separation of the ammonium phospho-molybdate in the case of the small amounts such as are usually found in rocks.

Carbon dioxide.—In the determination of CO_2 I would like to recommend to the consideration of chemists the gas volumetric method of LUNGE and MARCHLEWSKI, as described in TREADWALL (Hall), *Analytical Chemistry* (3rd. edition).

Instead of the tubes shown to the right in figure 61, a Lunge tube as shown in figure 116 of SUTTON'S *Volumetric Analysis* (9th. edition, p. 593) may be used, thereby dispensing with the compensation tube, and taking the barometer reading instead. KOH is admitted for absorption from the little cup at the top of the tube. The use of an air pump facilitates obtaining the necessary vacuum. The presence of H_2S may afterwards be identified in the KOH solution as required. This is a very reliable method, having the fewest sources of error, is quickly performed, and in my opinion is not excelled by any other method that I have tried.

Alkalies.—The precautions necessary to ensure accuracy in the determination of alkalies in rocks by the Lawrence-Smith method have been described by HILLEBRAND. In accordance therewith the chief loss has been considered to occur in the precipitate of lime removed from the aqueous extract of the original fusion.

During two years' experience, however, I have found that the residue from the above original fusion still contains alkali, and that a second fusion is necessary. The amount of alkali recovered by this second fusion amounts to about 3 milligrammes when half-gramme samples are used, or about .5 per cent. The presence of alkalies in the second fusion might be ascribed to lack of care in performing the first fusion and extraction. However, my own treatment of the first fusion has always been more than ordinarily careful, involving (1) fine grinding of the sample, (2) cooling of the crucible lid during fusion, (3) complete slaking of the lime after fusion by addition of the smallest quantity of water to the still hot cake, and (4) using at least 600 c.c. of wash-water raised to the boiling point.

II. THE TOTAL OR AGGREGATE PERCENTAGE.

A perfectly performed analysis would yield 100 per cent. if all the percipitates were pure, and the separations, determinations, manipulations, washings, etc., were carried out with entire accuracy.

There can be no exception to the statement by HILLEBRAND that, "a complete silicate rock analysis which foots up to less than 100 per cent. is generally less satisfactory than one which shows a summation somewhat in excess of 100." Such a statement, however, could very well be made from *a priori* considerations alone, without any reference to work experimentally determined. It implies that the operations of washing, ignition, separation, and determination connected with the analysis have been performed under practically ideal conditions. But a close approximation to 100, representing the summation of an actual analysis, is not conclusive evidence of perfect determination of the constituents of the rock, for this total includes errors of deficiency and excess, so-called "balance errors." Serious errors may exist under this often misleading category and the operator determines their extent in his work.

By a study of his work, as regards the range of summation above and below 100, the chemist may be led to suspect possible errors. For instance, if rocks of a certain general analytical composition yielded analyses whose totals generally fell at a certain point of deficiency or excess of 100, a clue might thereby be obtained as to the determination responsible for this discrepancy, and investigation could be made to determine the nature and cause of the error.

This method would of course be of least value in detecting errors (if any) in analyses which generally fell at 100 or a little beyond it, for the errors would be masked by the balance of "deficiency" and "excess" errors. But, on the other hand, in case no errors exist, such a neutral point in the vicinity of 100 would indicate the general analytical composition for the determination of which a certain method of analysis was best suited. In general, it should be recognized that the best methods that can be selected cannot be used indiscriminately for all classes of silicate rocks. Variations, based upon thorough study of different methods, must be used for rocks of different constitution. No method can be said to be known, or be unhesitatingly used, until the chemist has made such a study. Facility and accuracy in the general manipulations are not enough, and must be supplemented continuously, by the study of conditions and of the results obtained.

The variations from an ideal analysis may be considered as arising from a number of causes, amongst which may be mentioned, as stated by WASHINGTON, "actual loss of substance through spilling drops, etc., too much washing, (which may result in partial loss of slightly soluble precipitates), and finally, to the non-determination of some of the constituents which are actually present." It will be seen that the amounts of substance lost by spilling of drops, over-washing, and general manipulation, contributing to a summation less than 100, as well as those causes, mentioned by HILLEBRAND, that contribute to a summation greater than 100, viz., the dust entering during an analysis, incomplete washing of precipitates, and the impurities in the purest reagents—all these depend entirely on the operations of each individual chemist and the conditions under which his work is performed. Obviously, they will vary for different workers. The actual importance of these general causes of error would be difficult to estimate even in the case of an individual worker. However, the limits of summation above and below 100 should be fairly constant in the work of any one whose methods and practice have been reduced to a reasonable uniformity. Hence, each rock analyst will tend to have his own limit and range of aberration from a total of 100 per cent. Every careful chemist working under uniform conditions and methods should ascertain the general limits (above and below 100) into which his summation of analysis will fall, and use it for the purposes already stated.

It was in such a manner that my attention was drawn to the alkali determination for the purpose of increasing my percentage considerably, for, particularly in some instances, and to a less degree in many analyses, the summation was less than 100. The change in the method of alkali determination described above has given an increased percentage of alkalies and brought the total nearer to 100 per cent.; yet, previous to this no exception could have ordinarily been taken to the summation or to any single determination.

As a second example, I found that, in the analyses of rocks containing high percentages of iron, the total was frequently below the general range of summations. Of course this was an observation that required more than one analysis to establish, and led to the method given under determination of iron and alumina.

Excessive occasional variations of this kind, naturally, can only be avoided by applying correct modifications of method, and will be encountered oftener in analysis than those variations due to the more uniform operations of washing, etc. Hence a correction of this kind should, on the whole, lead to a still larger number of analyses falling within safe limits of summation.

ÜBER DIE PLASTIZITÄT DES STEINSALZES UND IHRE ABHÄNGIGKEIT VON DER TEMPERATUR.

VON

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Die Erkenntnis, dass Plastizität eine *quantitative* Eigenschaft kristallisierter Körper ist, und die Tatsache, dass diese Eigenschaft in der Nähe der Schmelzkurve einen hohen Grad erreicht, machte es wünschenswert, die Verhältnisse der Plastizität und ihre Abhängigkeit von der Temperatur in grosser Entfernung von der Schmelzkurve zu prüfen; für zahlreiche geologische Probleme ist die Plastizität der Mineralien und Gesteine gerade bei verhältnismässig niedrigen Temperaturen bedeutungsvoll.

Ein geeigneter Körper für derartige Untersuchungen fand sich im *Steinsalz*, dessen Plastizität, wie ich im Jahre 1909 zeigen konnte, in weiter Entfernung vom Schmelzpunkt durch verhältnismässig geringe Temperaturerhöhung in unerwartetem Masse zunimmt und schon bei 200° C. plastisch im gewöhnlichen Sinne des Wortes ist, während sein Schmelzpunkt bekanntlich über 800° C. liegt.[1] Die überraschend starke Zunahme des Plastizität lässt sich in einfacher Weise an Spaltungsstücken zeigen, denen man nach vorangegangener kurzer Erwärmung in der Alkoholflamme durch Biegen und Torquieren mit Hilfe von zwei Pincetten jede beliebige Gestalt geben kann.

In jüngster Zeit habe ich begonnen, zusammen mit mehreren Schülern die Abhängigkeit der Plastizität von der Temperatur *quantitativ* zu untersuchen, und möchte hier über die ersten Ergebnisse kurz berichten.

Aus grossen Steinsalzwürfeln wurden von den Hexaëderflächen begrenzte Stäbchen von annähernd 5 cm Länge und 8–10 mm^2 Querschnitt hergestellt, diese in einem Heizkasten auf zwei Achatschneiden gelegt und durch geeignete Vorrichtungen in dem während des Versuches geschlossen bleibenden Kasten belastet; die Biegung wurde durch einen Hebelarm angezeigt. Als Mass der Belastung diente die Bruchfestigkeit; die Belastung wird in Prozenten der Bruchfestigkeit ausgedrückt, die Zunahme der Plastizität erscheint am deutlichsten in der Biegungsgeschwindigkeit, der Angabe der Biegung in einer Zeiteinheit, der Minute. Die Bestimmungen konnten auf ziemlich niedrige Temperaturen (nicht über 200° C.) beschränkt bleiben, weil ich schon 1909 gefunden hatte, dass sich Steinsalzstäbchen in der Al-

[1] Neues Jahrbuch für Mineralogie, 1909, Bd. I, S. 60 ff.

kolbenflamme nach kurzer Erwärmung „wie Wachs" biegen lassen;[1] der Nachweis der leichten Biegsamkeit um beliebige, kristallographisch nicht definierbare Richtungen und die überraschende Torsionsfähigkeit hatten schon damals zu dem Schlusse gezwungen, dass durch Wärmezufuhr eine „Verringerung des Widerstandes gegen eine Formveränderung . . . sich allgemein, nicht ausschliesslich in kristallographisch bestimmten Richtungen geltend" macht (S. 72).[2]

Bei der Untersuchung *gespaltener Stäbchen* ergab sich bei 200° eine Biegungsgeschwindigkeit von durchschnittlich 0.3—0.5 mm in der Minute bei einer Biegungsbelastung von 60-75 prozent der Bruchbelastung; es wurden somit in kurzer Zeit—bis zu einer halben Stunde—Durchbiegungen von 16 mm erzielt, und die Versuche fanden ihr Ende lediglich durch Herabgleiten der stark gebogenen Stäbchen von den Schneiden. Durchaus ähnlich war das Verhalten der Stäbchen bei 150°; erst bei 100° machte sich eine bedeutende Verringerung der Biegungsgeschwindigkeit geltend, die auf 0.01—0.02 mm in der Minute sank, obwohl die Belastung etwas höher, 75—85 prozent der Bruchfestigkeit, gewählt wurde. Immerhin ist auch hier die Plastizität sehr bedeutend, und es wurden beträchtliche Biegungen erreicht, wenn auch gelegentlich schon Bruch eintrat.

Geht man von dem Mass der Biegung, beispielweise von 1 mm als Einheit aus, so zeigt sich, dass erhöhte Temperatur beschleunigend wirkt, dass man aber innerhalb gewisser Grenzen *die gleiche Biegung bei niederer Temperatur in längerer Zeit* erzielen kann. Wie Versuche ergaben, dauert es zunächst viel länger, bis eine Biegung überhaupt bemerkbar ist, sodann verläuft die eingeleitete Biegung auch langsamer, und es ist bei der gewählten Versuchsanordnung nicht möglich, so hohe Beträge wie bei höheren Temperaturen zu erzielen. Ein im Keller bei durchschnittlich 15° C. angestellter Versuch zeigte in 24 Tagen keine Biegung, am 27ten Tage war eine Biegung von 2.35 mm und am 29ten eine von 4.64 mm erreicht—dann trat ohne äussere Veranlassung Bruch ein.

Als wir nicht gespaltene, sondern sehr vorsichtig geschliffene Stäbchen anwendeten, ergab sich die merkwürdige Erscheinung, dass diese bei den niedrigeren Temperaturen weniger plastisch waren als die durch Spaltung hergestellten Versuchskörper. Versuche bei 200° ergaben noch eine Biegungsgeschwindigkeit von 0.02—0.03 mm in der Minute, bei 150° sank sie auf durchschnittlich 0.012 und es trat häufig Bruch ein, und bei 100° war nur sehr langsam und nur bis zu einem geringen Betrage eine Durchbiegung zu erzielen; die Biegungsgeschwindigkeit betrug 0.00006 mm und Bruch war die Regel.

Die Abhängigkeit der Plastizität von der Temperatur zeigt sich mithin bei geschliffenen Stäbchen in dem Temperaturintervall 100° bis 200° C. noch

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[1] Loc. cit., S. 63.

[2] In einer zwischen diesem Vortrag und seiner Drucklegung erschienenen Abhandlung zeigt A. RITZEL, dass sich Steinsalz bei 600° C. wie ein weicher *amorpher* Körper verhält (Zeitschrift für Kristallographie, 1913, Bd. LIII, S. 136. Anm während des Druckes.

deutlicher als bei Spaltungsstücken; auf die mögliche Ursache des Unterschiedes in dem Verhalten je nach der Herstellungsart möchte ich an dieser Stelle nicht eingehen, ebensowenig auf der Rolle der Gleitflächen bei diesem Vorgang und die Frage, ob diese die einzige Ursache sind, oder ob schon bei diesen verhältnismässig niedrigen Temperaturen die allgemeine Verringerung des Widerstandes gegen eine Formänderung unabhängig von der Richtung merklich mitwirkt.

Meiner Ansicht nach gibt dieses Verhalten des Steinsalzes nicht nur die Möglichkeit, gewisse Eigentümlichkeiten der Steinsalzlagerstätten zu erklären, sondern der Nachweis, dass Kristalle auch weit vom Schmelzpunkt entfernt Plastizität besitzen, und dass diese mit der Temperatur wächst, gestattet, in den *kristallinen Schiefern* einen Teil der bei gewöhnlichen Temperaturen spröden Minerale als plastisch anzunehmen und einen grösseren Teil der Komponenten dieser Gebilde als primär, aber plastisch deformiert anzusprechen, als es gegenwärtig in der Regel geschieht.

ON THE MODE OF DEPOSITION OF THE AURIFEROUS CONGLOMERATES OF THE WITWATERSRAND.

BY

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Geological Survey of South Africa, Pretoria

The Witwatersrand System of South Africa has more than a local interest, since with it are associated the most productive gold deposits the world has ever known. At the present time these deposits are the source of a yearly output of some £35,000,000, say $175,000,000, forming approximately one-third of the world's production. Mainly on this account the formation has attracted the interest of a large number of geologists and mining engineers in all parts of the world, many of whom have had opportunities of becoming personally acquainted with the Witwatersrand.

As is well known, the phenomenal gold deposits of the "Rand" are everywhere closely associated with certain beds of conglomerate, which form part of the Witwatersrand system, one of the oldest groups of sedimentary rocks in South Africa. A most important question, especially from an economic point of view, is the nature of the association of the gold with the pebble beds. Opinion is still divided as to whether the gold is an original constituent of the conglomerates, or whether it has been introduced at some period subsequent to that during which the conglomerates were laid down. Since the earliest days of the gold field this question has naturally been a subject of controversy among local geologists. Some of the more illuminating discussions, however, have been due to visitors from other parts of the world, who, perhaps because they were less influenced by a host of minor considerations of purely local value, have been able to take a more general view of the whole question.

In a very early paper on the Witwatersrand, published in 1892,[1] WALCOTT GIBSON of the Geological Survey of England and Wales took the view that the gold was an original constituent of the conglomerates and of alluvial origin. Later, in 1897, G. F. BECKER[2] of the U. S. Geological Survey wrote an account of the conglomerates which deals with many of the important questions involved. As a result of his examination of the local evidence, BECKER came to the conclusion that the gold was of alluvial origin and that the Rand conglomerates must be regarded as beach deposits laid down under the influence of coastal currents. More recently, in 1907, Professor J. W.

[1] Quart. Journal Geol. Soc. London, 1892.
[2] Eighteenth Ann. Rep. U. S. Geol. Surv., Pt. V., 1897

Gregory[1] (whose paper gives a concise review of the opinions previously advanced) adopted a similar view. He regards the conglomerates as marine placer deposits in which the gold has been concentrated by the action of tidal currents.

My own observations in the course of three years survey work on the Rand are strongly in favour of the view that the gold is of detrital or alluvial origin and was an original constituent of the conglomerates, although perhaps not exactly in its present form. There are, however, certain features of the conglomerates themselves which appear to me to be difficult of explanation if we regard these beds as simple shore deposits laid down under the influence of purely marine currents, and these features are perhaps of interest not only from a local but from a general geological point of view.

Perhaps one of the most important ends served by such a congress as the present one is the opportunity it affords for the exchange of opinions by geologists who, though working in widely separated areas, meet with similar problems for solution. This opportunity for discussion is perhaps most appreciated by those whose sphere of work lies more or less remote from the great centres of scientific activity, and who have consequently less frequent occasions for such interchange of opinion.

It is from this point of view that the present paper has been written, and its object is mainly to draw attention to certain features of the Witwatersrand conglomerates for which it would be interesting to find parallels in other localities where, perhaps, the conditions to which they are due may be more clearly indicated or more fully worked out.

It is unnecessary for the present purpose to refer in detail to the succession of strata constituting the Witwatersrand system, a practically complete section of which, as developed in the Witwatersrand area, has recently been given elsewhere[2] as a result of survey work during the past three years. A very brief statement will suffice to recall the main features of the system, which falls naturally into two divisions. Of these the Lower, some 15,000 feet in thickness, is characterized by an abundant development of argillaceous strata which, towards the base of the system, form the dominant beds. The Upper division, which on the Central Rand has an approximate thickness of 11,000 feet, consists, on the other hand, of an almost unbroken succession of coarse grits and conglomerates. The auriferous conglomerates of the Rand, which are only a few among a very large number of pebble beds occurring in the system, are found a little above the junction of the two divisions just referred to, that is to say, they were formed at about that period in the history of the Witwatersrand area when the tendency to the frequent recurrence of fine-grained deposits shown in the lower half of the system gave place to conditions under which an almost continuous succession of coarse sediments was laid down, or in other words, when, in that locality at least, a long period

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1 Trans. Inst. Min. and Met., 1907.

2 "*The Normal Section of the Lower Witwatersrand System*," Trans. Geol. Soc. of S. Africa, 1911, Vol. XIV, pp. 99-131. "*Structural Features of the Western Witwatersrand*." Trans. Geol. Soc. of S. Africa, 1913, Vol. XVI, pp. 1-32.

of deposition under comparatively quiet conditions of sedimentation gave place to one of rapid deposit of coarse materials, including a large number of pebble beds. Of these the most markedly auriferous members, to which profitable mining has been almost entirely confined, occur among the earliest formed conglomerates of the series.

A somewhat remarkable feature shown by the Witwatersrand system is the constancy of character exhibited by individual beds or groups of beds, which frequently maintain the same lithological peculiarities over the whole Witwatersrand.

This persistence of character is found not only in the larger members of the system but also in individual bands of quartzite or shale but a few feet in thickness. In several cases such bands can be shown to maintain their special lithological characters for a distance of twenty or thirty miles. This persistence of small individual members of the system is shown also to a remarkable extent by many of the conglomerate beds, a feature which appears to require some explanation.

A case in point is that of a bed of conglomerate which occurs about 10,000 feet above the base of the system and is known locally as the "Government Reef." This bed varies in thickness from three or four feet to that of a single pebble. It forms the base of a series of beds of quartzite with an aggregate thickness of 500 feet, and lies directly upon a series of ferruginous slaty beds which also attain a thickness of about 500 feet. This conglomerate forms one of the most useful stratigraphical datum lines in the Lower Witwatersrand system and can be traced with certainty over a tract of country some thirty miles in length. It is difficult to understand how such a bed as the conglomerate just referred to, following as it does immediately upon a long succession of argillaceous deposits, could be laid down by any ordinary marine current, unless this were subject to sudden changes in velocity or direction at widely separated intervals, and it would be interesting to learn whether any parallels are known among existing rock systems or among deposits at present in course of formation. There are several other instances in the Witwatersrand system of a persistent conglomerate bed directly succeeding a long series of argillaceous deposits.

These and several other similar occurrences, together with evidence of periods of very rapid sedimentation, suggest that during the deposition of the Witwatersrand system there was, in the neighbourhood of the Rand area at least, a source of abundant detrital material, and that this material was distributed by an agent which was subject to considerable and sudden variation, owing to which prolonged periods of comparatively slow accumulation of argillaceous material were followed by rapid deposition of coarser material, frequently beginning with a deposit of pebbles followed successively by coarse and then by finer arenaceous material. Such conditions appear to be most satisfactorily accredited, in part at least, to the action of one or more considerable rivers, possibly aided by coastal currents, than to that of marine currents alone, and the mode of succession and the character of the deposits appear to be such as might be expected to occur near the discharge of a considerable river. If, at considerable intervals of time, the Rand area had been brought either by local uplift or other means within reach of the coarser sediments discharged by such a stream, results such as are exhibited by the beds above referred to might be expected. In these earlier conglomerates of the Witwatersrand system the pebbles are of very uniform size, are well rounded and rarely exceed an inch or so in diameter. The conglomerate horizons are widely separated and the associated beds include a large proportion of argillaceous sediments. In the upper half of the system, on the other hand, argillaceous deposits are scarcely represented and the formation consists of a succession of coarse quarzites, grits and conglomerates, these last forming a considerable proportion of the total thickness. These conglomerates are very generally of large-pebbled types, the pebbles or boulders ranging up to a foot or more in diameter, and the whole suite of be' with which they are associated has the usual characteristics of deposits laid ..own in close proximity to a shore line. Thus, while we have in the uppermost part of the Witwatersrand system in-shore conditions of deposition with very coarse sediments and great irregularity of bedding, in the lower portions we find a succession of beds which were probably deposited at some distance from the actual shore-line of the period. Fine-grained material prevails in thes lower portions and the bedding is exceptionally regular and persistent.

In the middle portion of the system intermediate conditions prevail, conglomerate beds alternating with fine and coarse-grained sandy material that includes very occasional thin beds of argillaceous character. It is to this portion of the system that all the more important gold-bearing conglomerates belong, and they occur at a comparatively short distance above the top of the last considerable series of argillaceous beds.

The particular beds of conglomerate (locally called "reefs") which are the main source of the gold are few in number and lie near together in the vertical succession. They are known collectively as the "Main Reef series," as distinct from other "series" of "reefs," both these terms having a local meaning somewhat different from that usually assigned to them. The lowest or "Main Reef," which gives its name to the series, consists of a band of conglomerate ranging up to twelve feet or more in thickness and consisting of well smoothed and rounded pebbles that average from one to one and a half inches in diameter although there are occasional larger individuals. As a rule there is little appearance of grading of the material. The arrangement of the pebbles is often confused in character and the larger individuals may occur scattered through the mass. Definite arrangement in bands, though often seen, is not general but lenticles in which there is a predominance either of pebbles or of sandy matrix are of frequent occurrence. The gold content, which is usually very moderate, is similarly variable both in it quantity and with regard to its position in the reef. The whole deposit is such as one might expect to accumulate in a situation exposed to constantly varying currents, and very probably may represent a true shore deposit

The next member of the conglomerate se , known as the "Mai

Reef Leader," presents, as a rule, very different characteristics. The "reef" varies in thickness from about eight feet downwards. Very frequently there is a distinct grading of the pebbles, the larger individuals, which may reach two or three inches in diameter, being found very constantly on or near the actual foot of the bed and the size of the pebbles diminishing more or less regularly towards the upper portion. Very frequently the whole "reef" has the appearance of constituting a distinct "bed." Moreover, a distinct relationship is frequently observable between the size and character of the pebbles and the gold contents. The larger pebbles are usually associated with good values and the actual foot of the reef often shows visible gold, which is of very limited occurrence in the Rand deposits. A personal examination of the "Main Reef Leader" at frequent intervals along the long chain of mines in which it has been extensively worked has convinced me that it maintains its individuality as a geological unit throughout the whole of the Central Rand, that is, for a distance of fifteen miles at least. Followed westwards along the strike it gradually becomes thinner and of less economic value, and, after becoming intermittent and patchy, finally dies out altogether.

There is no reason to think that the persistence of this bed for so great a distance along the outcrop is in any way due to approximate parallelism between the present outcrop and an original shore line along which the conglomerate might have been laid down. Moreover, the conglomerate bed is known to have an extension of many thousands of feet in a direction approximately at right angles to the line of outcrop. An even greater persistence is shown by a third member of the Main Reef series lying at a somewhat higher horizon and known as the "South Reef." The unusual persistence of these conglomerate beds strongly recalls that shown by other beds which, like the "Government Reef," occur in the lower part of the system, and to which reference has already been made. Such persistence appears to be scarcely compatible with an origin as simple marine shore deposits. The peculiarities of several of the beds suggest that they have been laid down in a comparatively short time, and have resulted from the redistribution and re-sorting of a large body of previously accumulated material by currents considerably more powerful than those normally at work in the neighbourhood. Such currents might be occasioned by an exceptional discharge from an extensive catchment area after abnormal rainfall such as is known to have occurred at widely separated intervals in the history of many regions with which we are acquainted. The diversion, at a time of exceptional flood, of the main channel of discharge of a great continental river having extensive estuarine deposits might conceivably result in the rapid sweeping away of large quantities of previously accumulated material already roughly graded and, practically in the same operation, its re-distribution over a new area, thus giving rise to deposits very similar in character to some of the Rand conglomerates. In the case of several of these beds which show a marked continuity and which should probably be regarded as individual deposits, the available data suggest that they form continuous lenticular patches with an extension in all directions of many miles. That such deposits should be laid down by individual floods of exceptional force that caused the rapid re-distribution of large quantities of previously accumulated material does not seem an improbable solution, and it appears to account more reasonably than many others for the somewhat remarkable features presented by certain of the Rand conglomerates, especially the persistence of individual beds. At the same time it appears also to supply a reasonable explanation of several peculiarities in the distribution of the gold in certain of the conglomerate beds and of the differences shown by them in this respect as compared with others of the series, *e.g.* the differences between the Main Reef Leader and the Main Reef itself.

This is a view which a study of the Witwatersrand system as a whole, and of the auriferous conglomerates in particular, has suggested, and it would be both interesting and valuable to have the criticism and comment of a gathering like the present Congress, which most probably includes among its members some who have met with similar conditions elsewhere, either among rock formations or deposits of comparatively recent origin or those still in course of deposition.

The extent to which any single geological stratum may be due to what may be described as a single episode in deposition, is a question about which definite data appear to be extremely difficult to obtain, and indeed the whole question of the various modes of deposition of conglomerates is one in connection with which a wide field for investigation, interesting alike to the stratigraphist and the economic geologist, lies open. The very nature of the conditions of deposition of conglomerates, which so often involve the partial destruction of a bed soon after its formation, renders the subject a difficult one, and it is perhaps to the physiographer dealing with deposits still in course of formation that we may look for more light on this interesting geological problem.

PETROLEUM ON BONDOC PENINSULA, TAYABAS PROVINCE, PHILIPPINES.[1]

BY

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INTRODUCTION.

History and development.—The existence of petroleum seeps on Bondoc peninsula became generally known soon after the American occupation of the Philippines, although no mention of petroleum in Tayabas appears in the geological and mining publications of the former Spanish government. Within the past few years a number of companies have been organized and claims have been located far and wide throughout the region, but development has not gone further than the drilling of two shallow wells. Each of these encountered oil but neither yields a quantity great enough to class it as successful. However, the wells are close together, neither is more than 100 metres deep and they are not in a situation which could be considered highly favourable from a geological standpoint. That they were not successful, therefore, fails as evidence upon which to condemn the whole field.

Literature.—Published description of Bondoc peninsula is meagre. GEORGE F. RICHMOND,[2] investigated the physical and chemical properties of samples of the petroleum collected by the Division of Mines in 1910. F. T. EDDINGFIELD[3] published a short paper on the geology of the field containing two diagrammatic cross sections of the structure. A general geological reconnaissance[4] by GEO. I. ADAMS and the writer contains a reference to Bondoc peninsula.

Situation.—The Tayabas oil field includes the southern half of a distinctly peninsular area which extends with regular, parallel coast lines S. S. E. from the southern part of the mainland of Luzon. A constant width of about 20 kilometres persists throughout the southern portion of the peninsula to the very end, and, since petroleum seeps are known on both the east and the west coasts, the oil field assumes a rectangular outline 20 kilometres wide by 50 kilometres long.

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[1] Synopsis of an article on the Tayabas oil field by WALLACE E. PRATT and WARREN D. SMITH to be published in a forthcoming number of the Philippine Journal of Science.

[2] *Tayabas Petroleum*; Phil. Journ. of Sci., Vol. V (1910), A, No. 1, p. 1.

[3] *Tayabas Oil Fields*; Min. Res. of the Philippine Islands for 1910 (1911), p. 64.

[4] *Geologic Reconnaissance of Southeastern Luzon*; Phil. Journ. Sci., Vol. VI, (1911), Sec. A, No. 6, p. 449.

Catanauan and Mulanay, the principal coast towns in the southern part of the peninsula, are about 300 kilometres distant from Manila by steamship line. Inland from these towns only rough trails serve for transportation. Away from the coast the population is sparse and the country is unimproved. Occasional herds of cattle are encountered over the great stretches of alternately wooded and open country.

GEOLOGY.

Physiography.—The contour of the peninsula, the character of the land forms and the alignment of the drainage all reflect strongly the geological composition and the structure of the region. Over the south half of the oil field the land rises from the coast to a relatively high, generally level or rolling plateau with deeply incised narrow valleys trending S. S. E. along the main water courses. The general level of this high table-land is 250 to 300 metres. The extreme heights are slightly above 400 metres, while the rivers cut down to an elevation of 100 metres within a short distance from their heads. Farther north the general elevation is lower (100 metres) and the land forms are more mature, the rivers meandering in wide valleys throughout the lower halves of their courses.

The high, level areas occupy broad, gentle synclines while the ridges developed locally, especially along parts of the lateral coast lines, represent the steep limbs of narrow, sharp anticlines, which characterize the structure of the peninsula. The valleys in turn follow the crests of the anticlines, even in the topographically young region to the south. This early translation of the water courses from their probable initial position along structural valleys to the crests of the adjacent anticlines finds some explanation in the character of the highest member of the geologic formation, which is a thick-bedded to massive limestone. It is conceived that this naturally rigid upper limestone member would respond to flexing stresses by breaking rather than bending, and that the resultant fractures and dislocation planes would develop to a far greater extent along the anticlines, which have been already described as sharp and narrow, than in the relatively wide, gentle synclines.

Stratigraphy.—The following table is a tentative correlation of the stratigraphic column for Bondoc peninsula. The paleontologic study and the age determination are by WARREN D. SMITH.

For the purposes of this general discussion the younger formations require no description further than that contained in the table. The constitution and thickness of each of the divisions vary, the characteristics of shallow-water deposition alone being persistent. They are above the horizon at which oil has been observed and any accumulation of petroleum is probably independent of their presence. The Kanguinsa sandstone, a compact impervious rock, is often encountered immediately above the Bacau shale. In this position the Kanguinsa sandstone might serve as a confining roof for the oil in the Bacau shale, but its function as such is probably unimportant because the shale itself is close grained and does not afford a reservoir from which petroleum would escape readily.

The volcanic agglomerate is limited in extension to the northeast corner of the petroleum-bearing area and occurs in three small exposures only. It is composed of andesite fragments in a scanty cement that is likewise andesitic, and probably tuff. Apparently it is very similar to the andesitic ag-

PROVISIONAL SCHEME OF STRATIGRAPHY, BONDOC PENINSULA, TAYABAS.

Period.	Formation.	Character.	Thickness metres.	Characteristic fossils.
Recent.	Alluvium.	Clay, sand, gravel.	0—10	
Pleistocene.	Littoral deposits.	Raised coral reefs, beaches, etc.	0—30	*Trochus fenestratus, Cerithium nodulosum, Telescopium telescopium, Conus flavidus.*
Pliocene and Miocene.	Malumbang series.	Upper ls., coralline to sandy.	20—50	*Lucina bacanensis, Cerithium sp., Pyrula gigas, Solecurtus grandis, sp. nov., Spondylus imperialis, Operculina costata, Bulla ampulla, Pecten senatorius,* large *Lepidocyclina, Cycloclypeus communis.*
		Kadiapi ss., bedded, calcareous, yellow to brown, and locally concretionary.		
		Lower ls., coralline to sandy.	0—15	
		Kanguinsa ss., blue to gray, massive; includes thin beds of ls. with coarse quartz-sand and pebbles.		
Unconform. (?)	....	Volcanic aggl.	?	
		Bedded ss.-congl.	5	*Mitra sp., Pyrula sp*
Lower Miocene or Oligocene.	Bacau shale.	Massive, bluish to brownish black and fine grained.	50—100*	*Globigerina.*
	Vigo shale.	Gray, yellow and brown, thin bedded, sandy shale	1,000 base not exposed *	*Polystomella.*
Unconformity.	...	....	......	
Eocene.	....	Hidden or lacking.		
?	....	Basal congl. over diorite.		

NOTE: *oil horizon; ss. = sandstone; ls. = limestone; congl. = conglomerate; aggl. = agglomerate.

glomerates which occur in oil fields of both Japan and Sumatra. It is found in Tayabas at two horizons, one exposure being overlain by the Kanguinsa sandstone and the other two appearing in the Bacau shale.

The principal evidence of an unconformity in the lower division of the Miocene period is the occurrence of the volcanic agglomerate and a rather abrupt steepening in the inclination of the strata below the Kanguinsa sandstone relative to the overlying beds. The conglomerate at this horizon is bedded conformably with the Bacau shale beneath it.

The Bacau shale is very fine grained, bluish to brownish-black and indistinctly bedded. It is mainly a compact, indurated clay, but contains also thin sandy lenses. The beds immediately above and below it are carbonaceous, but the Bacau shale contains little carbon although it emits a strong odour of petroleum. The fossil shells in it are covered with a film of oil or grease and appear upon fresh exposure to be remarkably well preserved. Any attempt to remove them, however, reveals a tendency to crumble, similar to the effect produced upon limestone by calcination. Fresh surfaces in the shale itself appear to be greasy. The material weathers into concretion-like ellipsoidal pieces, which break down further through the splitting off of concentric layers into small fragments with conchoidal surfaces. The formation may be regarded as the upper 50 to 100 metres of the Vigo shale, since the two are not sharply distinct.

The Vigo shale is characteristically thin-bedded and the successive beds are varyingly more and less sandy. In spite of these evidences of changing conditions of deposition, the formation is extensive and uniform over large areas. It grades insensibly into the Bacau shale above, while its base is not exposed within the area under discussion. Occasional strata appear to be identical in character with the material in the Bacau shale, but more generally the Vigo shale is sandy and yellow to brown in colour. Thin beds of sandstone occur in it and appear to be more abundant in the upper portion. An apparent thickness of at least 1,000 metres of Vigo shale is exposed in the limbs of the principal anticline in the field and the section does not include the base of the formation.

Structure.—Bondoc peninsula is anticlinal in structure but the arch is not accomplished in a single, simple fold. A principal, central anticline follows the axis of the peninsula and may be traced for a distance equal to one-half of the length of the oil field. Flanking the central anticline on either side is a minor fold marked by small anticlines that occur at intervals along a line roughly parallel to the axis of the main anticline. The central anticline and the line of anticlines along each coast are sharp flexures, while the intervening synclines are broad and shallow, so that, although the peninsula as a whole is an anticlinorium in structure, the greater proportion of the land mass is contained within synclines.

The central anticline is inclined to the east and pitches to the south. The beds near the axis dip almost vertically in the eastern limb and at an angle of about 40° in the western limb. The eastern limbs of the anticlines along the eastern coast are similarly steep and are likewise more highly inclined than the western limbs, while along the western coast both limbs of the anticlines are flatter, with the western limbs steeper. In the northern part of the region erosion has cut away the crest well down into the Vig shale on the central anticline, while farther south only the upper beds of the Vigo formation are exposed; and at the extreme southern end of the peninsula, owing to the southerly plunge of the anticlinal axis, even these are intact. The minor anticlines are eroded less deeply than the central anticline.

PETROLEUM.

Occurrence.—Petroleum is indicated on Bondoc peninsula by seeps of gas and oil at widely separated points throughout the region. The seeps occur invariably near the crests of anticlinal folds and always at about the horizon of the Bacau shale. In several instances the oil oozes directly from the Bacau shale, but in at least one case it appears to come from the Vigo shale. Gas, unaccompanied by oil, is emitted at a number of places. No discolouration of the strata by the escaping petroleum can be detected, but an odour of light oil is noticeable in the neighbourhood of a petroleum seep. The wells which have been drilled obtained their oil from the Bacau shale.

Physical properties of the petroleum.—The first analyses of Tayabas petroleum made by RICHMOND,[1] showed so large a proportion of the fraction distilling below 150° C. that suspicion was aroused as to the authenticity of the sample. Later examination of samples collected at one of the wells by the Division of Mines confirmed the first results and proved that the petroleum contained an unusually large percentage of light oils.

Tayabas petroleum is light brown to wine-red in colour by transmitted light and blue by reflected light. It loses part of its lighter constituents readily upon exposure, and because of this fact, specific gravity determinations on different samples have shown variation. One sample tested as low as 0.805 in specific gravity while the heaviest recorded sample had a specific gravity of 0.845. A representative sample subjected to fractional distillation in the Division of Inorganic Chemistry, Bureau of Science, by Mr. E. R. DOVEY, gave the following results:

Composition of Tayabas crude petroleum.

Crude Oil:	specific gravity at 29°C. . .	0.8323
	Refractive index at 30°C. .	1.4639
Gasoline:	(0-150°C.) by volume......	30.4 per cent.
	Specific gravity at 30°C. .	0.7692
Kerosene:	(150-300°C.) by volume ...	50.9 per cent.
	Specific gravity at 28°C. . .	0.8333
	Flash point (open cup).....	42°C.
	Fire point.................	54°C.
Heavy oil:	(300-400°C.) by volume....	15.1 per cent.
	Specific gravity at 28°C. . .	0.9061
Residue:	(above 400°C.) by weight ...	3.6 per cent.
Sulphur:	....	Absent.

[1] *Tayabas petroleum*; Phil. Journ. of Sci., Vol. V. (1910), A, No. 1, p. 1.

The lighter fraction of this oil proved to be lævorotatory to the extent of 0.55°. RICHMOND found 30 per cent. of unsaturated hydrocarbons in the crude oil, 16 per cent. in the gasoline fraction and 24 per cent. in the kerosene fraction. The same authority reports 8.1 per cent. of paraffin in the crude oil.

Origin of the petroleum.—There is some evidence that the Bacau shale is the source of the petroleum encountered in it. SMITH has identified numerous Globigerina in the shale and considers it probable that petroleum may have originated from the decomposition of the fleshy part of these organisms. The Globigerina are not present, however, in as great abundance as would seem to be demanded to account for even the limited quantity of petroleum in these beds and it has been suggested that a lower horizon, probably in the unexposed portion of the Vigo shale, may be the real source of petroleum, some of which, having diffused upward, is now encountered in the Bacau shale.

The strata below the Bacau shale, so far as they are exposed, show evidence of petroleum only rarely. However, an oil with the character of the Tayabas product might leave in the rocks little or no trace of its passage through them. The Bacau shale, for example, loses every indication of its petroliferous character after a short period of exposure to air. Hence it is possible that petroleum exists in the unexposed lower beds of the Vigo shale, from which small quantities have migrated along favourable channels to the surface, where the oil has been completely dissipated from all the rocks except those which, like the close grained Bacau shale, are suited to retain it most tenaciously. From the well-known principles of fractionation by diffusion through a porous medium, the light clarified nature of the oil might be taken to confirm the theory of migration.

Economic considerations: possible development.—The existence of petroleum on Bondoc peninsula is established, although the quantity which may be available is undetermined.

Judging from the situation of oil seeps in Tayabas relative to the structure, and from experience in the productive field of Palembang, Sumatra, where the geologic conditions apparently are very similar to the conditions in the Tayabas field, the petroleum would be expected to have accumulated in the anticlines in accordance with the general anticlinal theory. If oil has tended to collect in the anticlines, then the structure in parts of the peninsula must be considered favourable (anticlines intact above the oil horizon) for the retention of the oil under conditions which would permit of commercial exploitation.

If no petroleum is found other than the small quantity which occurs in the Bacau shale, a large commercial production is not to be anticipated. However, it appears that wells in the Bacau shale could be made to yield small individual flows. This shale is petroliferous and probably the unbroken sandstone lenses which it contains are saturated with petroleum. The thinness of the sandstone beds indicates that their lateral extent is also limited. Consequently it should be possible to space wells closely without mutual interference. The area over which such wells could be located is large, and the aggregate possible production from the Bacau shale might be of commercial importance. If petroleum is encountered in the unexposed base of the Vigo shale, the chances of a large production are better.

Under the circumstances, Bondoc peninsula must be classed as an unproven oil field where there is a chance of obtaining petroleum economically. Owing to the reluctance of adequate capital to engage in Philippine enterprises, it has been suggested that, on the chance of developing a valuable natural resource, the government undertake the initial exploration of the region. If this plan prevails, wells will be drilled upon public land by t Bureau of Public Works at sites to be determined by the Division of M. Bureau of Science.

Contributions diverses: Paléontologie et physiographie.

ÉTUDE DU STIPE DE L'ASTEROPTERIS NOVEBORACENSIS,

PAR

PAUL BERTRAND,

Maître de Conférences de Paléontologie Houillère à l'Université de Lille.

Avec une planche.

L'*Asteropteris noveboracensis*, Dawson, est une fougère dévonienne, qui fait partie de la famille des Zygoptéridées, ordre des Inversicaténales. Elle provient du *Portage group* de Milo (État de New York) et fut décrite par J. W. DAWSON en 1881. Plusieurs circonstances rendaient très désirable une étude nouvelle de cette curieuse fougère. Tout d'abord il était devenu indispensable de vérifier les résultats de DAWSON, en tenant compte des progrès réalisés depuis trente ans dans l'étude des fougères anciennes et récentes; il s'agissait de savoir si l'*Asteropteris* était bien une Zygoptéridée, et si l'on pouvait préciser sa position systématique par rapport aux autres membres de la même famille. On pouvait aussi espérer éclaircir, grâce à l'*Asteropteris*, les problèmes relatifs à la mystérieuse famille des Cladoxylées. D'ailleurs, on sait combien sont rares les végétaux à structure conservée, trouvés dans le Dévonien; on ne saurait donc étudier trop minutieusement les quelques spécimens que nous possédons, qui peuvent nous fournir des indications précieuses sur le degré d'évolution de la flore à cette époque. Enfin, la comparaison de l'*Asteropteris* avec les plantes de la même famille pourra dans une certaine mesure nous aider à fixer l'âge des couches où il a été trouvé.

M. FRANK D. ADAMS a eu l'amabilité de m'envoyer un fragment de l'échantillon original de DAWSON. J'ai pu avec ce fragment obtenir deux sections transversales très voisines l'une de l'autre[1]; ce sont ces deux sections qui font l'objet de la présente communication. Qu'il me soit permis de présenter ici à M. FRANK D. ADAMS l'expression de ma profonde reconnaissance.

HISTORIQUE.—APERÇU GÉNÉRAL SUR L'ASTEROPTERIS.

Pour exposer rapidement et clairement ce qu'est l'*Asteropteris noveboracensis*, il me paraît à la fois plus commode et plus intéressant de reproduire d'abord la description originale de DAWSON.

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[1] Ces deux sections ont été faites par M. LÉON ROLAND, Préparateur à l'Université de Louvain (Belgique), qui possède une très grande habileté dans ce genre de travaux. Je lui adresse ici mes sincères remerciements.

"*Notes on new Erian (Devonian) plants.*" [1]

"*Asteropteris noveboracensis*, gen. and sp. nov.—The genus *Asteropteris* is established for stems of ferns having the axial portion composed of vertical radiating plates of scalariform tissue embedded in parenchyma and having the outer cylinder composed of elongated cells traversed by leaf-bundles of the type of those of *Zygopteris*."

"The only species known to me is represented by a stem 2.5 centimetres in diameter, slightly wrinkled and pitted externally, perhaps by traces of aerial roots which have perished.[2] The transverse section shows in the centre four vertical plates of scalariform or imperfectly reticulated tissue, placed at right angles to each other, and united in the middle of the stem. At a short distance from the centre, each of these plates divides into two or three, so as to form an axis of from ten to twelve radiating plates, with remains of cellular tissue filling the angular spaces. The greatest diameter of this axis is about 1.5 centimetres. Exterior to the axis the stem consists of elongated cells, with somewhat thick walls and more dense towards the circumference. The walls of these cells present a curious reticulated appearance, apparently caused by the cracking of the ligneous lining in consequence of contraction in the process of carbonization. Embedded in this outer cylinder are about twelve vascular bundles, each with a dumb-bell-shaped group of scalariform vessels enclosed in a sheath of thick-walled fibres. Each bundle is opposite to one of the rays of the central axis. The specimen shows about two inches of the length of the stem and is somewhat bent, apparently by pressure, at one end."

"This stem is evidently that of a small tree-fern of a type, so far as known to me, not before described, and constituting a very complex and symmetrical form of the group of Palæozoic ferns allied to the genus *Zygopteris* of Schimper.[3] The central axis alone has a curious resemblance to the peculiar stem described by Unger ("Devonian Flora of Thüringia") under the name of *Cladoxylon mirabile;* and it is just possible that this latter stem may be the axis of some allied plant. The large aerial roots of some modern tree-ferns of the genus *Angiopteris* have, however, an analogous radiating structure."

"The specimen is from the collection of Berlin H. Wright, Esq., of Penn Yan, New York, and was found in the Portage group (Upper Erian) of Milo, New York, where it was associated with large petioles of ferns and trunks of *Lepidodendra*, probably *L. chemungense* and *L. primoevum*."

La description de DAWSON est remarquablement concise et exacte. Avec un rare bonheur, l'auteur a dit tout ce qu'il avait pu voir de cette plante énigmatique. D'emblée, il lui a assigné sa place exacte dans la classification.

1 J. W. DAWSON, *Quarterly Journ. Geol. Soc. London*, Vol. XXXVII, 1881, p. 299, Pl. XII, fig. 1 à 9. Cette description est reproduite textuellement dans DAWSON, *The geological history of fossil plants*, London, 1888, p. 95.

2 Cette assertion de DAWSON paraît inexacte, car on n'aperçoit aucune trace de racines sur la section transversale.

3 Le genre *Zygopteris* a été créé en réalité par CORDA.

à côté des *Zygopteris* et il a signalé sa ressemblance incontestable avec le *Cladoxylon mirabile* d'UNGER. C'était à cette époque tout ce que l'on pouvait dire sur l'*Asteropteris*. La description de DAWSON était accompagnée de quelques dessins justificatifs (Pl. XII, fig. 1 à 3, et 5 à 9) montrant les faits observés par l'auteur, et d'un essai de restauration (Pl. XII, fig. 4).

La communication de DAWSON sur l'*Asteropteris* fut présentée à la Société Géologique de Londres le 23 Juin 1880. CARRUTHERS, qui assistait à la séance, s'éleva contre les affinités indiquées par le savant canadien et soutint que l'*Asteropteris* était une Lépidodendrée.

En 1889, G. STENZEL[1] classa l'*Asteropteris* dans la section *Clepsydropsis* du genre *Asterochlæna*, Corda.

Depuis STENZEL, les auteurs qui se sont occupés des Zygoptéridées ont eu général réuni simplement le genre *Asteropteris* au genre *Asterochlæna*.

En 1909, j'ai pensé à le rapprocher du genre *Metaclepsydropsis*; mais, en 1911, j'ai reconnu qu'il constituait un genre distinct à la fois de *Clepsydropsis*, de *Metaclepsydropsis* et d'*Asterochlæna*.[2]

ÉTUDE DÉTAILLÉE DU STIPE.

L'*Asteropteris* est une fougère herbacée à stipe dressé, non pas une fougère arborescente, comme on pourrait le supposer si l'on prenait à la lettre l'expression de DAWSON (tree-fern). La description de DAWSON, reproduite ci-dessus, est suffisamment claire; je puis donc passer immédiatement à l'étude détaillée des régions du stipe.

Dans cette étude, je me suis trouvé limité par l'état de conservation de l'*Asteropteris* qui est assez défectueux. Les deux sections transversales dont je disposais sont malheureusement un peu obliques; pour ces raisons, je n'ai pu obtenir qu'un petit nombre de photographies. Je reproduis (pl., p. 923) les plus démonstratives.

L'étoile ligneuse.—Le bois forme une étoile à branches *irrégulièrement ramifiées*. Il y a bien au centre quatre lames, mais ces lames n'étaient certainement pas disposées à angle droit les unes sur les autres, comme le suppose l'essai de restauration tenté par DAWSON. Elles paraissent groupées par deux et réunies par une courte barre transverse qui est malheureusement rompue (Fig. 1 du texte, page 912).

Deux de ces lames se bifurquent en donnant chacune deux branches (Nos. I et II, VI et VII, fig. 1 du texte); la troisième se divise en trois branches (Nos. III, IV et V). Quant à la quatrième, elle n'est pas visible sur nos préparations; elle se divisait probablement aussi en trois. L'étoile ligneuse toute entière comprenait donc 10 à 12 branches, comme l'a annoncé DAWSON.

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[1] G. STENZEL, *Die Gattung Tubicaulis, Cotta*; Mitt. aus dem Kgl. Min. Geol. Museum in Dresden, Heft VIII, 1889.

[2] P. BERTRAND, *Études sur la fronde des Zygoptéridées*, Lille, 1899.
——— *Structure des stipes d'Asterochlæna laxa Stenzel*; Mem. Soc. Géo. du Nord, T. VII, Mém. No. 1, 1911.
——— *L'étude anatomique des Fougères anciennes et les problèmes qu'elle soulève*; Progressus rei botanicae, Vol. IV, 1912, p. 255.

On peut voir sur nos figures, que ces branches sont de longueur variable, mais il est certain que toutes jouent le même rôle au point de vue de l'émission des traces foliaires.[1]

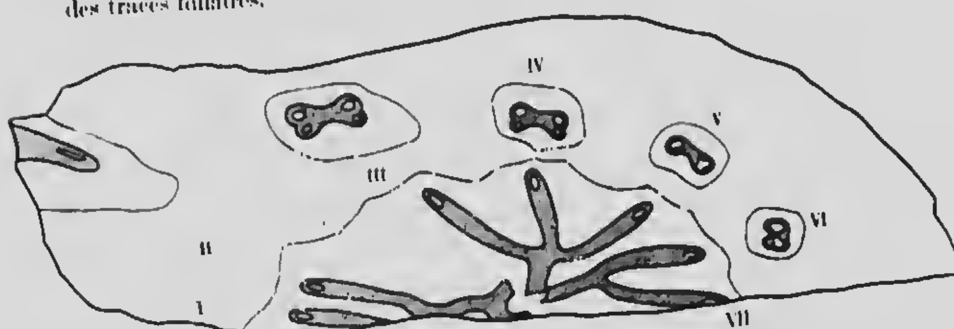

FIG. 1. *Asteropteris noveboracensis*, Dawson.—Section transversale du stipe, montrant l'étoile ligneuse entourée de traces foliaires. Les branches de l'étoile ont été numérotées de I à VII.

Toutes les lames ligneuses sont pleines, sauf à leur extrémité libre; elles sont composées de vaisseaux de petit calibre (15 à 25μ). Nos préparations, étant aldiques, se prêtent parfaitement à l'étude des ornements des vaisseaux. Ces ornements sont des raies courtes, séparées par des échelons; partout où l'état de conservation est suffisant, ils ont toutes les apparences d'ornements scalariformes. Mais souvent, il semble qu'il y ait deux séries longitudinales (parfois même, trois séries) de ponctuations (ou raies très courtes) sur la même face d'un élément, d'où un aspect réticulé qui avait frappé DAWSON.[2] On sait que, pour beaucoup d'auteurs, le type réticulé serait plus primitif que le type scalariforme. Il y a donc intérêt à déterminer la nature des ornements des vaisseaux ligneux sur une plante aussi ancienne que l'*Asteropteris*. Il serait possible en particulier, que les vaisseaux d'*Asteropteris* représentent une forme d'éléments intermédiaire entre le type scalariforme et le type réticulé.

Cette supposition n'est pas exacte. J'ai examiné à plusieurs reprises attentivement les éléments de l'étoile ligneuse d'*Asteropteris* et je conclus. (1) que ces éléments sont de véritables vaisseaux scalariformes et non pas une variété de vaisseaux scalariformes; (2) que l'aspect réticulé qu'ils présentent souvent est dû uniquement à l'altération de leurs parois.

J'ai examiné de même le bois des traces foliaires sortantes. Les éléments sont ici plus gros que dans l'étoile ligneuse. En section longitudinale, on n'aperçoit que des ornements scalariformes.[3] En section oblique, on re-

[1] La tige est un peu aplatie parallèlement au grand côté de la préparation; cependant, on voit nettement que la branche No. III est plus longue que ses deux voisines, No. IV et No. V.

[2] Cet aspect est assez fidèlement reproduit sur la figure 6 de DAWSON.

[3] Cette remarque s'applique à la trace foliaire No. II, qui est rencontrée très obliquement par la coupe; en fait, les éléments ligneux de cette trace sont vus en section longitudinale sur une très grande longueur

connaît bien également les ornements scalariformes. Sur quelques gros éléments, au centre de la trace foliaire, on croit voir, il est vrai, les raies se dédoubler en deux lignes; mais cette apparence paraît due, comme précédemment, à l'altération des parois.

Protoxylème.—A l'extrémité de chacune des branches de l'étoile, on observe une espèce de *boutonnière* (=*boucle polaire*=*boucle périphérique*). C'est sur le pourtour de cette boutonnière, qu'étaient situés les éléments de protoxylème (*PX*, fig. 2, pl., p. 923). L'intérieur de la boutonnière est rempli par un tissu parenchymateux peu visible, tout imprégné de produits bruns. Ces boucles périphériques sont rigoureusement comparables à celles que l'on trouve dans la trace foliaire des *Clepsydropsis*.

Les intervalles entre les branches de l'étoile étaient remplis par un tissu composé de cellules irrégulières à parois minces. Ce tissu, partiellement détruit, est pourtant bien visible en quelques points (*TF*, figs. 1 et 2, pl.).

Tout contre les branches de l'étoile, il y avait une mince couche de liber. Mais je n'ai pas réussi à la voir avec netteté. On aurait une idée de ce tissu, soit par le liber qui tapisse les branches de l'étoile ligneuse d'*Asterochlaena*, soit par celui qui tapisse la trace foliaire de *Clepsydropsis*.

Écorce. Nous avons signalé le tissu à parois minces remplissant les baies de l'étoile ligneuse. Le reste de l'écorce est constitué par un tissu sclérifié épais dans lequel sont plongées les traces foliaires. Ce tissu est composé de grandes cellules, à contour arrondi ou polygonal (fig. 1, pl., p. 923). Les cellules situées dans les couches les plus profondes sont plus petites et plus serrées.[1] Les parois des cellules sclérifiées ne sont pas très épaisses; elles étaient peut-être couvertes de ponctuations. En tout cas, l'aspect réticulé qu'elles présentent maintenant, est dû à l'altération qu'elles ont subie sous l'influence du retrait, comme DAWSON l'avait pensé.

De nombreuses cellules, plus grandes que les autres, à contour arrondi, ont probablement joué un rôle sécréteur.

En section longitudinale, les cellules de l'écorce sont deux fois plus longues que larges. Elles sont séparées par des cloisons obliques.

La surface du stipe (épiderme et tissu sous-jacent) manque.

Les traces foliaires.—Sur nos préparations, on voit cinq traces foliaires (numérotées de II à VI, fig. 1 du texte) plongées dans l'écorce et placées chacune en face d'une des branches de l'étoile. Ces traces appartiennent évidemment à un même verticille; mais par suite de l'obliquité des sections, la trace foliaire No. II se trouve plus éloignée de l'étoile; la trace foliaire No. VI, située à l'autre extrémité de la préparation, se trouve plus rapprochée.

La trace foliaire No. IV est la mieux conservée; elle offre une masse ligneuse, étranglée en son milieu, renflée à ses extrémités qui sont pourvues chacune de deux boucles périphériques (*P1*, *P2*, fig. 3, pl., p. 923). Les figures publiées par DAWSON représentaient des traces foliaires en *clepsydre*, c'est à dire pourvues d'une seule boucle périphérique à chaque extrémité. La structure de la trace foliaire est en réalité plus compliquée qu'il ne l'avait supposé.

[1] Contrairement à l'opinion de DAWSON qui a trouvé les cellules plus serrées vers la périphérie.

La trace foliaire offre un aspect nettement zygoptéridien. Elle rappelle la trace foliaire des *Diplolabis* et des *Stauropteris* (trace foliaire quadripolaire en forme d'X). Au premier abord, elle paraît pourvue de deux plans de symétrie: un plan de symétrie principal et un plan de symétrie droite-gauche; mais on constate sur toutes les traces foliaires que les deux boucles périphériques antérieures sont toujours notablement plus petites que les deux postérieures. Il y a donc suppression du plan de symétrie droite-gauche. A cet égard, la trace foliaire d'*Asteropteris* serait comparable à celles des *Ankyropteris* et des *Asterochlæna*.

On pourrait supposer que les deux petites boucles périphériques antérieures représentent deux sorties hâtives. Cette hypothèse me paraît inexacte. Je pense que les deux boucles antérieures font partie intégrante de la trace foliaire.

La trace foliaire No. VI, qui est la plus rapprochée de l'étoile, est plus trapue et se montre pourvue de deux boucles périphériques seulement, dont l'une est, il est vrai, en voie de division. La trace foliaire No. V paraît aussi n'avoir qu'une seule boucle périphérique à chaque extrémité.

D'après les données précédentes, on peut se représenter assez aisément les premiers états de la trace foliaire:

Niveau 1.—La trace foliaire est émise aux dépens de la boucle périphérique qui termine l'une des branches de l'étoile. Il est donc à peu près certain que l'état le plus simple de la trace foliaire est un état annulaire, avec pôles situés sur le bord interne de l'anneau.

Niveau 2.—Un peu plus haut, la trace foliaire s'étrangle en son milieu; par suite de la division du système polaire central, elle se montre pourvue d'une boucle périphérique à chaque extrémité (Traces foliaires No. VI et No. V, fig. 1 du texte).

Niveau 3.—Plus haut encore, chaque boucle périphérique se divise à son tour en deux; la trace foliaire prend l'aspect quadripolaire que nous lui voyons sur les traces Nos. II, III et IV (fig. 1 du texte; figs. 1 et 3, pl., p. 923).

Malheureusement, nous ne pouvons rien dire sur ce que devient la trace foliaire en s'élevant dans le pétiole primaire de la fronde. Il est possible qu'elle ait acquis dès maintenant ses caractéristiques essentielles, mais il est plus probable qu'elle subit encore des transformations importantes en passant dans le pétiole primaire.

Autour de la trace foliaire, on observe de grandes lacunes radiales; ces lacunes étaient occupées par un tissu fondamental à parois minces, qui a subi un retrait considérable. Le liber enveloppant la trace foliaire est indiqué par une couche brune de cellules écrasées.

POSITION SYSTÉMATIQUE DE L'ASTEROPTERIS NOVEBORACENSIS.

L'*Asteropteris noveboracensis* est bien un stipe de Zygoptéridée à frondes verticillées, comme DAWSON l'avait annoncé. Cette conclusion est basée sur les faits suivants:

1. Le stipe d'*Asteropteris* est pourvu d'une étoile ligneuse dont la structure est comparable à celle des stipes d'*Asterochlæna*.

2. Autour de l'étoile ligneuse, on observe des masses sortantes; il est impossible de considérer ces masses autrement que comme des traces foliaires. On ne peut pas admettre en particulier que toutes ces masses sortent ensemble dans un même organe latéral; leur état de différenciation exclut immédiatement cette hypothèse. Ces traces foliaires sont des traces zygoptéridiennes, mais chez lesquelles le plan de symétrie droite-gauche tend à disparaitre. Ce que l'on peut voir de leurs états sucessifs montre, qu'en s'échappant, elles prennent les mêmes aspects que les traces foliaires des autres Zygoptéridées (voir fig. 3 du texte).

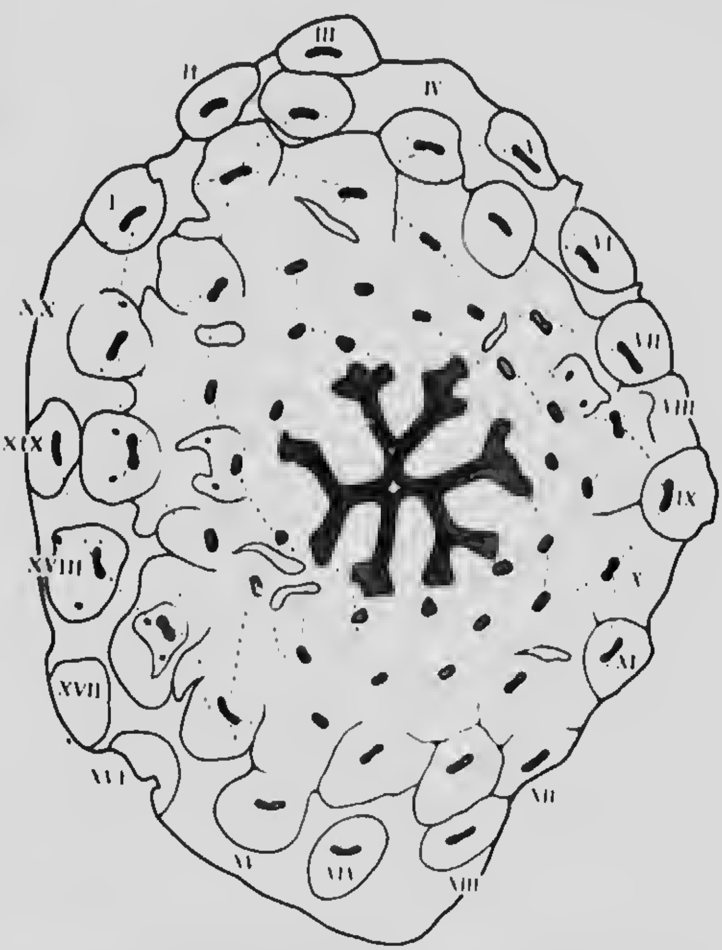

FIG. 2.—*Asterochlæna laxa*, var. *Solmsi*, P. Bertrand.—Section transversale du stipe montrant la disposition verticillée des traces foliaires. Les lignes pointillées représentent les hélices foliaires. Les nombres de I à XX désignent les séries radiales de traces foliaires.

3. La disposition verticillée des frondes rappelle également les *Asterochlæna*.

Il nous reste maintenant à préciser, si possible, la position systématique de l'*Asteropteris* dans la famille des Zygoptéridées.

On sait que cette famille renferme de nombreux genres disposés suivant plusieurs séries parallèles. Nous examinerons successivement les relations de l'*Asteropteris* avec les *Asterochlæna*, puis avec *Diplolabis* et *Stauropteris*, enfin avec le *Zygopteris Kidstoni*.

Relations de l'Asteropteris avec les Asterochlæna.—L'agencement des branches de l'étoile ligneuse d'*Asteropteris* rappelle à première vue la structure des stipes d'*Asterochlæna*, comme on peut s'en assurer en comparant les figures 1 et 2 du texte. Dans les deux cas, les frondes sont disposées en verticilles très réguliers; mais les branches de l'étoile se jettent les unes sur les autres sans aucune régularité.

Entre *Asteropteris* et *Asterochlæna* on relève les différences suivantes:

1. Chez *Asteropteris*, les lames ligneuses sont pleines jusqu'au centre de l'étoile, mais pourvues d'une boucle périphérique à leur extrémité libre Chez les *Asterochlæna*, il n'y a pas de boucles périphériques; les pôles sortants destinés aux traces foliaires sont ponctiformes (Fig. 3 du texte). Par contre, il y a des *bandes médianes de protoxylème* qui occupent la région moyenne des lames ligneuses et s'avancent jusqu'au centre de l'étoile.[1]

2. Chez *Asteropteris*, toutes les branches de l'étoile sont *unilobées*. Chez *Asterochlæna*, elles sont presque toujours *bilobées* ou *trilobées*; cela est dû a ce que chacune d'elles alimente deux ou trois génératrices foliaires (Fig. 2 du texte). Il est exceptionnel de rencontrer une branche unilobée, c'est-à-dire n'alimentant qu'une seule génératrice foliaire.

3. Chez *Asteropteris*, il y a 10 à 12 frondes à chaque verticille et les verticilles sont superposés. Chez *Asterochlæna*, chaque verticille comprend aussi 10 à 12 frondes (parfois 13 à 14), mais comme il y a alternance d'un verticille au suivant, il y a au total deux fois plus de génératrices foliaires que chez *Asteropteris*. *Asterochlæna* possède de 20 à 22 génératrices foliaures et autant de *sommets* à l'étoile ligneuse (c'est-à-dire de points d'émission de traces foliaires.)

4. Enfin la trace foliaire d'*Asterochlæna*, (Fig. 3 du texte), pourvue seulement de deux boucles périphériques, est moins élevée en organisation que celle d'*Asteropteris*. Au contraire, le stipe d'*Asterochlæna* est beaucoup plus différencié que celui d'*Asteropteris*.

Tous ces caractères montrent qu'*Asteropteris* constitue un genre nettement distinct d'*Asterochlæna*.

Relations de l'Asteropteris avec les genres Diplolabis et Stauropteris.—Par la structure de sa trace foliaire (masse libéro-ligneuse quadripolaire

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[1] Les éléments ligneux sont des vaisseaux scalariformes chez *Asterochlæna* comme chez *Asteropteris*.

en forme d'X), le genre *Asteropteris* se placerait à côté des genres *Stauropteris* et *Diplolabis*.—Chez *Stauropteris*, la trace foliaire présente une masse ligneuse pourvue de quatre pôles intérieurs au bois. Les pôles sont habituellement *ponctiformes;* mais il peut y avoir des boucles périphériques. M. W. T. GORDON m'a montré une section transversale d'un pétiole de *Stauropteris burntislandica*, sur laquelle l'un des massifs ligneux était pourvu d'une *boucle polaire* (*peripheral loop*), au lieu d'un pôle ponctiforme.

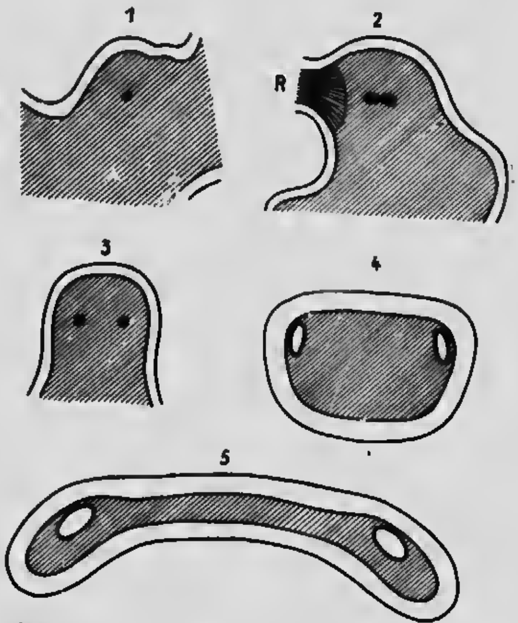

FIG. 3.—*Asterochlæna laxa*, var *Solmsi*. P. Bertrand.—États successifs de la trace foliaire. 1, trace foliaire pourvue d'un seul pôle intérieur au bois; 2, division du pôle, R, racine; 3, état bipolaire; 4, état clepsydroïde; 5, trace foliaire à son plein épanouissement dans le pétiole primaire.

Dans le pétiole primaire de *Diplolabis*, la masse ligneuse a la forme d'un X; chacune des branches est recourbée en crochet à son extrémité; les quatre pôles sont situés à la face interne des crochets; ils sont extérieurs au bois. Mais quand la trace foliaire de *Diplolabis* rentre dans le stipe, les quatre crochets peuvent se fermer et donner quatre boucles périphériques:[1] la trace foliaire de *Diplolabis* ressemble alors étonnamment à celle d'*Asteropteris*.

Il faut remarquer cependant que chez *Stauropteris* et *Diplolabis* la trace foliaire est pourvue d'un plan de symétrie droite-gauche; chez *Asteropteris*, il y a perte de ce plan de symétrie, les deux boucles antérieures étant plus petites que les deux boucles postérieures. A cet égard, la trace foliaire

[1] W. T. GORDON, *On the structure and affinities of Diplolabis Romeri de Solms;* Trans. Royal Soc. Edinburgh, Vol. XLVII, Pt. IV, No. 24, 1911.

d'*Asteropteris* rappelle celle d'*Ankyropteris* et d'*Asterochlæna*, mais elle s'en écarte par d'autres caractères.

Les affinités entre *Diplolabis* et *Asteropteris* ne sont certainement pas étroites. Les études de M. Gordon ont montré, en effet, que le stipe de *Diplolabis* est pourvu d'une masse ligneuse pleine à contour circulaire,[1] très différente de l'étoile ligneuse d'*Asteropteris*.

D'autre part, le stipe de *Stauropteris* est encore inconnu; dès lors, il est impossible de pousser plus loin la comparaison avec *Asteropteris*.

Relations de l'Asteropteris avec le Zygopteris Kidstoni.— Je signalerai enfin, pour mémoire, une certaine analogie entre le stipe de l'*Asteropteris* et celui du *Zygopteris Kidstoni*. Des deux côtés, on a une étoile ligneuse compacte avec formation de boucles périphériques pour l'émission des traces foliaires. Mais l'étoile ligneuse du *Z. Kidstoni* est réduite à cinq branches courtes; les frondes sont disposées suivant le cycle $\frac{2}{5}$; la structure de la trace foliaire est inconnue

En résumé, le genre *Asteropteris* doit être placé provisoirement à côté du genre *Asterochlæna*. Pour préciser davantage sa position systématique, il parait indispensable de savoir d'abord ce que devient la trace foliaire à son plein épanouissement dans le pétiole primaire.

RELATIONS DE L'ASTEROPTERIS AVEC LES CLADOXYLÉES.

Les *Cladoxylées* sont des plantes énigmatiques du Dévonien supérieur de Saalfeld en Thüringe. Bien qu'elles aient été décrites par Unger en 1854, leur structure est encore imparfaitement connue et leur position systématique demeure indéterminée. Dawson ayant signalé une curieuse ressemblance entre l'*Asteropteris* et le *Cladoxylon mirabile* d'Unger, on pouvait espérer résoudre le problème des *Cladoxylées* au moyen de l'*Asteropteris*. Mais cette espérance ne parait pas se réaliser.

Les tiges de *Cladoxylon* renferment, comme celles d'*Asteropteris*, des lames ligneuses rayonnantes, pourvues à leur extrémité d'une boutonnière ou boucle périphérique. J'ai moi-même été très frappé de ces analogies; de plus, j'ai observé à la périphérie des tiges de *Cladoxylon* des masses ligneuses annulaires; j'avais tout lieu de supposer que ces anneaux représentaient chacun une trace foliaire sortante, qui, plus haut, devait revêtir l'aspect classique de la trace zygoptéridienne. J'ai donc conclu de mes premières études[2] que les *Cladoxylon* d'Unger étaient des stipes de *Zygoptéridées*, analogues à l'*Asteropteris*, et j'ai défendu cette manière de voir jusqu'en 1912.

L'étude plus complète que j'ai faite des échantillons d'Unger ne me permet pas de maintenir plus longtemps cette conclusion. M. de Solms-

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1 W. T. Gordon, *loc. cit.*

2 P. Bertrand, *Sur les stipes de Clepsydropsis;* C.-R. Acad. d. Sciences, Paris, 16 Novembre, 1908.

——— *Observations sur les Cladoxylées;* C.-R. Assoc. Franc. pour l'Avanc. d. Sciences, Dijon, 1911.

LAUBACH avait décrit, dès 1896, un pétiole en connexion avec le *Cladoxylon Solmsi* (=*Cl. dubium* de SOLMS, *non* UNGER.)[1] J'ai constaté à mon tour que tous les *Cladoxylon* portent des organes latéraux que l'on est en droit de considérer comme des pétioles. Ces organes ont une structure beaucoup plus complexe que les pétioles des *Zygoptéridées*. Ils offrent, comme la tige, plusieurs lames ligneuses rayonnantes, terminées chacune par une boucle polaire. Mais ils diffèrent de la tige par leur symétrie bilatérale très nettement marquée. Ces organes ont été décrits par UNGER, sous les noms de *Hierogramma* et de *Syncardia* (Fig. 6 du texte).

D'autre part, si l'on examine la façon dont ces organes prennent naissance sur les tiges de *Cladoxylon*, on constate que *plusieurs anneaux ligneux sor-*

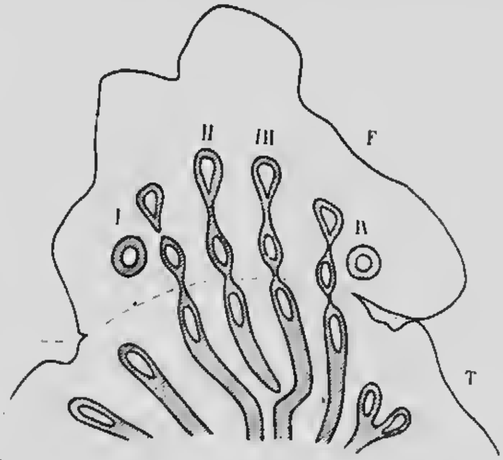

FIG. 4.—*Cladoxylon radiatum*, Unger, *sp.*—Fragments de tige montrant l'émission d'une trace foliaire. (D'après la préparation No. 15871 du Jermyn Street Museum de Londres).

T, tige; F, base d'un pétiole primaire, encore adhérent à la tige; I et IV, groupes tripolaires; II et III, groupes bipolaires.

tants, émis aux dépens de plusieurs lames ligneuses rayonnantes, se rendent simultanément dans le même pétiole.

Nous prendrons comme exemple l'émission de la trace foliaire chez *Cladoxylon radiatum* (voir fig. 4 du texte). Cette émission est produite aux dépens de 4 à 6 lames ligneuses consécutives; chaque lame donne deux anneaux sortants à la suite l'un de l'autre. A la base du pétiole primaire, la trace foliaire offre régulièrement la structure suivante: au centre de la trace, il y a deux groupes de deux anneaux ligneux chacun (=*groupes bipolaires*); à chaque extrémité de la trace, il y a un groupe de trois anneaux (=*groupe tripolaire*) ou bien un seul anneau triangulaire.

[1] H. DE SOLMS-LAUBACH, *Über die seinerzeit von Unger beschr. strukturbiet. Pflanzenreste des Unterculm von Saalfeld in Thür.*; Abh. d. Kgl. Pr. Geol. Landesanstalt, Neue Folge, Heft XXIII, 1896. Le travail de M. DE SOLMS constitue une préface indispensable à l'étude des Cladoxylées.

Chez *Cladoxylon radiatum*, on observe au total 10 anneaux ligneux sortants (Fig. 4 du texte), disposés sur une courbe aplatie dont le plan de symétrie passe par l'axe de la tige. Les deux anneaux extrêmes sortent bientôt chacun dans une *aphlebia*. Il reste huit anneaux qui s'allongent d'abord tangentiellement, puis radialement. Après diverses transformations, la trace foliaire revêt très probablement la structure des *Hierogramma*,[1] (Fig. 6 du texte).

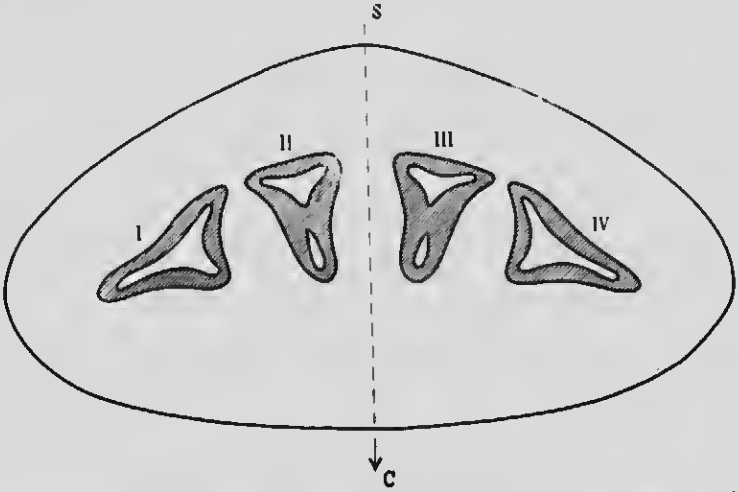

Fig. 5.—*Cladoxylon dubium*, Unger.—Section transversale d'un pétiole primaire coupé près de sa base, montrant la structure de la trace foliaire.
S C. plan de symétrie passant par l'axe de la tige; I et IV, groupes tripolaires; II et III, groupes bipolaires.

Chez *Cladoxylon Solmsi* et *Cl. dubium* (Fig. 5 du texte), on observe la disposition suivante à la base du pétiole: au centre de la trace foliaire, deux groupes de deux anneaux ligneux chacun (=*groupes bipolaires*); à chaque extrémité de la trace, un anneau triangulaire (=*groupe tripolaire*). Cette disposition est évidemment comparable à celle décrite plus haut chez *Cladoxylon radiatum*.[2]

On n'observe rien de pareil chez l'*Asteropteris*, ni chez les autres Zygoptéridées.

Les Cladoxylées demeurent par conséquent des végétaux très isolés et très énigmatiques. Par la structure de leurs tiges, elles rappellent certaines Zygoptéridées: *Ankyropteris*, *Asterochlæna*, et surtout *Asteropteris*. Mais la trace foliaire des *Cladoxylon* (Figs. 4, 5 et 6 du texte) est beaucoup plus complexe que la trace zygoptéridienne. Théoriquement, on pourrait

1 Malheureusement, les états successifs par lesquels passe la trace foliaire d'un *Cladoxylon*, avant d'acquérir la structure d'un *Hierogramma*, n'ont pas pu être observés.

2 En examinant l'ensemble de la section transversale de *Cladoxylon radiatum*, on constate, en outre, que les pétioles F sont disposés en hélice autour de la tige, probablement suivant le cycle ⅜.

dire que la trace zygoptéridienne est une trace de *Cladoxylon* réduite à deux ou à quatre lames rayonnantes (*Clepsydropsis*, *Stauropteris*).

On sait que les traces foliaires des Phanérogames anciennes, comparées à celles des Fougères de la même époque, s'en distinguent généralement par le nombre plus grand de leurs faisceaux. On peut conclure de là que les Cladoxylées offrent plus d'affinités avec les Phanérogames qu'avec les Fougères anciennes. Peut-être même, devrait-on les classer dès maintenant parmi les Phanérogames. Les analogies de structure constatées entre les tiges de *Cladoxylon* et celle de l'*Asteropteris* seraient le résultat d'une convergence.

POSITION STRATIGRAPHIQUE DE L'ASTEROPTERIS NOVEBORACENSIS.

Les *Clepsydropsis* trouvés à Saalfeld en Thüringe, à Sémipalatinsk (Sibérie) sont vraisemblablement les Zygoptéridées les plus anciennes que

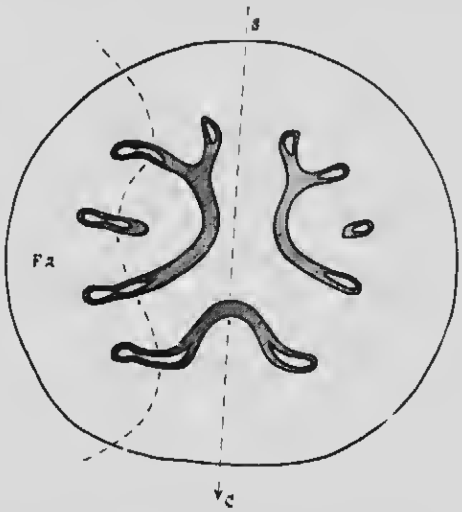

FIG. 6.—*Cladoxylon insigne*, Unger, sp. (Forme *Hierogramma*).—Section transversale d'un pétiole primaire montrant la structure de la trace foliaire.

S C, plan de symétrie passant par l'axe de la tige; F 2, système sortant destiné à un pétiole secondaire.

N.B.—Les *Hierogramma* d'Unger représentent très probablement les pétioles primaires des *Cladoxylon*. (Comparer entre elles les figs. 4, 5 et 6 du texte.)

nous connaissions; en tout cas, ils possèdent la trace foliaire la plus simple; cette trace renferme une lame ligneuse pourvue d'une boucle périphérique à chaque extrémité. Or, les *Clepsydropsis* proviennent du Dévonien supérieur. Logiquement, on doit supposer que l'*Asteropteris* qui possède une trace foliaire plus différenciée que les *Clepsydropsis* est plus récent. Il serait donc tout au plus du Dévonien supérieur. Cette conclusion est en accord avec les assertions de DAWSON, qui considère que l'Érien supérieur correspond au Dévonien supérieur.[1] Toutefois, pour être certain que l'*Asteropteris* est bien contemporain des *Clepsydropsis*, il faudrait trouver ces derniers dans les mêmes couches.

RÉSUMÉ.

Conformément aux conclusions de DAWSON, l'*Asteropteris noveboracensis* est une fougère appartenant à la famille des Zygoptéridées. Elle offre les caractères suivants:

1. Le stipe est dressé; il mesure environ 2.5 cm. de diamètre. Dans ce stipe, on trouve une étoile ligneuse compacte offrant 10 à 12 branches; chaque branche est pourvue d'une boucle polaire (peripheral loop) à son extrémité; elle n'alimente qu'une seule génératrice foliaire. Les vaisseaux ligneux sont des vaisseaux scalariformes.

2. Les frondes sont verticillées avec superposition d'un verticille au suivant. Les traces foliaires possèdent une masse ligneuse en forme d'X, pourvue de quatre boucles polaires. Il y a perte du plan de symétrie droite-gauche, les deux boucles antérieures sont plus petites que les deux postérieures.

3. Le stipe de l'*Asteropteris* rappelle beaucoup les stipes d'*Asterochlæna* du Permien; mais il offre une structure plus simple que ces derniers.

D'autre part, la trace foliaire d'*Asteropteris* rappelle surtout celle des *Diplolabis* et des *Stauropteris*. Elle en diffère par la perte du plan de symétrie droite-gauche. Comme nous ignorons ce que devient la trace foliaire en s'élevant dans le pétiole primaire, il ne nous est pas possible de préciser davantage la position systématique de l'*Asteropteris* dans la famille des Zygoptéridées. Provisoirement, il convient de les laisser à côté des *Asterochlæna*.

4. Le stipe d'*Asteropteris* offre une ressemblance singulière avec les Cladoxylées d'UNGER. On trouve des deux côtés une masse libéro-ligneuse étoilée pourvue de boucles polaires. Mais l'étude détaillée des Cladoxylées conduit à les séparer des Zygoptéridées et même des Fougères, pour les rapprocher des Phanérogames anciennes.

5. L'*Asteropteris* ne paraît pas être antérieur au Dévonien supérieur.

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[1] D'après les divisions actuellement admises par les géologues pour le Dévonien de l'Amérique du Nord, l'Érien ne sert plus à désigner qu'une assise du Dévonien moyen. Mais les *couches de Portage* se placent dans le Dévonien supérieur à la partie supérieure du Famennien.

P. BERTRAND. PLANCHE.

Fig. 1 Fig. 2

Fig. 4 Fig. 3

Asteropteris noveboracensis, Dawson.

EXPLICATION DE LA PLANCHE.

Fig. 1. Ensemble de la section transversale du stipe, montrant l'étoile ligneuse et 5 traces foliaires sortantes. Gr. = 4,7

F, *F*, traces foliaires sortantes;

TF, tissu fondamental à parois minces, partiellement détruit, remplissant les baies entre les branches de l'étoile.

Fig. 2. Extrémité d'une branche de l'étoile ligneuse. Gr. = 66.

PX, boucle polaire (peripheral loop), sur le pourtour de laquelle on trouverait les éléments de protoxylème;

TF, tissu fondamental à parois minces.

Fig. 3. Section transversale d'une trace foliaire sortante et de la branche de l'étoile ligneuse qui lui a donné naissance. Gr. = 20.

PX, boucle polaire (peripheral loop), située à l'extrémité d'une des branches de l'étoile;

P^2, boucle polaire postérieure de la trace foliaire;

P^1, boucle polaire antérieure, plus petite que la boucle postérieure.

Fig. 4. Tissu fondamental sclérifié, constituant l'écorce. Gr. = 20.

LA FAUNE CONTINENTALE DU TERRAIN HOUILLER DU NORD DE LA FRANCE: SON UTILISATION STRATIGRAPHIQUE.

PAR

PIERRE PRUVOST,

Lille, France.

L'étude paléontologique du bassin houiller du Nord de la France, poursuivie depuis quelques années à l'Institut de Géologie de l'Université de Lille (Musée houiller), par M. P. Bertrand et par moi, sous la direction de M. le professeur Ch. Barrois, a fourni certains résultats d'une portée générale qui m'ont paru susceptibles d'intéresser le Congrès.

D'un côté, au point de vue paléobotanique, les recherches de M. P. Bertrand et de M. l'abbé Carpentier donnent aux études de M. R. Zeiller une importante confirmation, en précisant et définissant l'extension des zones végétales que ce savant a distinguées, en 1886, dans le bassin de Valenciennes.

D'un autre côté, les études du Musée houiller de Lille, activement secondé par les Ingénieurs des Compagnies houillères, ont encore pour résultat de faire connaître les faunes marines du bassin qui occupent dans l'épaisseur du terrain houiller des niveaux fixes, indiqués par M. Ch. Barrois comme devant fournir des points de refère stratigraphiques précieux.

Enfin, une grande partie de la faune qui habitait, non plus la mer, mais le continent où se formait la houille, nous est connue et c'est de ces animaux que je voudrais dire quelques mots. Leur étude est capable, croyons-nous, de rendre à son tour quelques services.

COMPOSITION DE LA FAUNE CONTINENTALE HOUILLÈRE DU NORD DE LA FRANCE.

On peut répartir en trois groupes les animaux qui nous sont actuellement connus pour avoir vécu dans le Nord de la France à l'époque westphalienne, en outre des fossiles marins. Nous énumérerons séparément les éléments de cette faune adaptés à la vie en eau douce ou saumâtre, à la vie terrestre et à la vie aérienne.

Faune aquatique.

Elle comprend des poissons, des crustacés, des lamellibranches et des vers.

POISSONS.

Crossoptérygiens.

Strepsodus sauroides, Binney.[1]
Rhizodopsis sauroides, Williams.[1]
Cœlacanthus elegans, Newb.
Cœlacanthus mucronatus, nov. sp.
Ctenoptychius, sp.

Hétérocerques: Paléoniscidés.

Elonichthys, cf. *Aitkeni*, Traquair.
Elonichthys, cf. *semistriatus*, Traq.
Elonichthys, sp.
Rhadinichthys Macconochii, Traq.[1]
Rhadinichthys monensis, Egert.
Rhadinichthys, sp.

Platysomidés.

Cheirodus granulosus, Young.
Mesolepis scalaris, Young.

Sélaciens, Cestraciontidés?

Palæoxyris appendiculata, Lesq.[3]

CRUSTACÉS.

Ostracodes.

Carbonia fabulina, Jones and Kirkby.[3]
" *rankiniana*, J. et K.[3]
" *pungens*, J. et K.[3]
" *scalpellus*, J. et K.[3]
Cypridina radiata, J. et K.[3]

Phyllopodes.

Estheria striata, var. *Tateana*, Jones.[3]
" *Simoni*, Pruvost.[3]
Estheriella Renmauxi, Pruv.[3]
Leaia tricarinata, Meek et Worthen.

Gigantostracés.

Eurypterus, sp.[4]

Xiphosures.

Belinurus reginæ, Baily.[4]
Prestwichia Danæ, Meek et Worth.[4]
" *rotundata*, Prestw.[4]

Arthropleuridés.

Arthropleura armata, Jordan.[5]

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1 M. LERICHE. *Première note sur les poissons carbonifères du Nord de la France*, Ann. Soc. géol. du Nord, T. XXXVII, p. 266, pl. VII.

2 Ces pontes de Cestracionidés (ou de Cochliodontidés?) sont toujours rencontrées dans les formations d'eaux douces du terrain houiller, tandis que les poissons auxquels elles semblent appartenir sont cantonnés dans les sédiments marins. Ce fait se vérifie dans le bassin du Nord de la France. Il est donc logique de supposer que ces animaux marins remontaient pour pondre à l'intérieur des terres dans les lagunes et les étangs.

3 P. PRUVOST. *Note sur les entomostracés du terrain houiller du Nord de la France*; Ann. Soc. géol. du Nord. T. XL, p. 60, pl. I, II.

4 P. PRUVOST. *Note sur quelques crustacés du terrain houiller du Nord de la France*, Ibid., T. XL, p. 295, pl. VII.

5 P. PRUVOST. *Sur la présence du genre Arthropleura dans le terrain houiller du Nord et du P. d. C*; Ibid., T. XLI, p. 57, pl. II.

LAMELLIBRANCHES.[1]

Unionidés.

Carbonicola acuta, Sow.
" *turgida*, Brown.
" *similis*, Brown.
" *aquilina*, Sow.
Anthracomya modiolaris, Sow.
" *Williamsoni*, forme *pulchra*, Hind.
" *Williamsoni*, Brown.
" *minima*, Ludwig.
" *Phillipsii*, Williams.

Mytilidés.

Naiadites modiolaris, Sow.
" *carinata*, Sow.
" *quadrata*, Sow.

ANNÉLIDES.

Spirorbis pusillus, Martin.[2]

Au point de vue de leur mode de vie, on peut diviser les fossiles de cette liste en deux catégories. La plupart d'entre eux, et en particulier les lamellibranches, les ostracodes et les phyllopodes, présentent ceci de particulier qu'on ne les trouve jamais associés à des fossiles franchement marins comme les *Lingules* et les *Productus*. On peut donc les considérer en toute certitude comme des fossiles adaptés à la vie en eaux douces. Je ne connais aucun exemple dans le bassin du Nord de la France où ils se dérobent à ce caractère et pareil fait a déja été observé dans les bassins belges par M. A. RÉNIER.

D'autres moins nombreux,—ce sont ceux d'entre ces fossiles qui se meuvent le plus aisément,—en particulier les poissons (*Rhadinichthys* et *Cœlacanthus*), les *Eurypterus* et les *Prestwichia*, sont parfois trouvés, mais rarement et en petit nombre, dans les niveaux à *Lingules* et à *Productus*. Ils s'accommodaient d'un certain degré de salure des eaux au début de la période westphalienne, mais ils deviennent manifestement adaptés à l'eau douce un peu plus haut dans le terrain houiller.

Faune terrestre.

La faune terrestre actuellement connue du terrain houiller du Nord de la France comprend des araignées et des myriapodes.

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[1] W. HIND. *Les faunes conchyol. du t. h. de la Belgique*; Mem. Mus. Roy. Hist. Nat. Belg., T. VI, 1911. Les espèces de lamellibranches indiquées dans cette liste sont figurées dans l'ouvrage précité et dans le mémoire de M. W. HIND: *Anthracomya*, *Carbonicola*, *Naiadites*, Pal. Soc. Lond., 1894-1896.

[2] CH. BARROIS et A. MALAQUIN. *Sur les spirorbes du t. h. de Bruay*; Ann. Soc. géol. du Nord, T. XXXIII, p. 50, pl. II.

Araignées.

Eophrynidés.

Hemikreischeria Geinitzi, Thévenin.[1]

Kreischeria? Vailleti, Pruvost.[2]

Aphantomartus areolatus, Pocock.[2]

" *Pococki*, Pruv.[2]

Brachypygidés.

Maiocercus celticus, Pocock.[2]

Myriapodes.

Eileticus, cf. *aqualis*, Scudd.[4]

Faune aérienne.

On a recueilli récemment dans le bassin houiller du Nord de la France, un assez grand nombre d'insectes, seuls habitants de l'air à l'époque carbonifère. En voici la liste[5]:

Insectes.

Protorthoptère.

Climaconeura Remauxi, Pruv.

Blattoïdes; Archimylacrides.

Actinoblatta Bucheti, Pruv.

Archimylacris belgica, Handl.

" *Desaillyi*, Leriche.[6]

" *Simoni*, Pruv.

Phyloblatta Hanneryi, Pruv.

" *Carletteri*, Pruv.

" *Morini*, Pruv.

Mylacrides.

Necymylacris Vailleti, Pruv.

" *Lafittei*, Pruv.

" *Godoni*, Pruv.

Soomylacris, sp.

Orthomylacris, sp.

Stenomylacris Montagnei, Pruv.

Ainsi qu'il ressort de ces listes, la faune qui habitait le continent du Nord de la France à l'époque houillère était extrêmement variée. Il semble qu'à l'heure présente on n'ait guère exhumé encore qu'une faible partie de ses représentants. Il est permis de supposer toutefois que ce sont là les plus communs de ses éléments et on peut essayer dès maintenant d'en tirer certains enseignements théoriques et surtout quelques applications stratigraphiques utiles.

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[1] A. Thévenin. Proc. Verh. Soc. Hist. Nat. Autun, Vol. XV, p. 195.

[2] P. Pruvost. *Note sur les araignées du t. h. du N. de la France*; Ann. Soc. Géol. du Nord, T. XLI, p. 85, pl. IV.

[3] L'empreinte de cette espèce récemment découverte à Aniche fixe les caractères de la tête jusqu'ici inconnue dans la famille des Brachypygidés; le bouclier céphalothoracique est segmenté et très semblable à celui des Eophrynidés.

[4] P. Pruvost. *Note sur un myriapode du t. h. du Nord*; Ibid. T. XLI, p. 65, pl. II.

[5] P. Pruvost. *Les Insectes houillers du N. de la France*; Ibid., T. XLI, p. 323, pl. IX à XII.

[6] M. Leriche. Ibid., T. 36, p. 164, pl. II.

COMPARAISON DE LA FAUNE CONTINENTALE HOUILLÈRE DU NORD DE LA FRANCE AVEC CELLE DES AUTRES RÉGIONS.

Au point de vue paléontologique pur, les fossiles recueillis dans le bassin houiller du Nord ont fourni, concernant la structure de certaines formes mal connues, leurs affinités et leur mode de vie, une série de renseignements précieux dont l'examen sortirait du cadre de cette vue d'ensemble.

Un autre résultat général de leur découverte a été de souligner de façon très nette les affinités étroites qui existent entre la faune de ce bassin et celle des bassins anglais et belges qui l'avoisinent. Les listes que j'ai données sont tout à fait comparables, à quelques détails près, avec celles que l'on a dressées déjà pour ces autres bassins. Ce sont bien les mêmes espèces de *Carbonicola* et d'*Anthracomya*, d'après ce dont j'ai pu me rendre compte par l'examen des belles collections du Musée Royal d'Histoire Naturelle de Bruxelles, la même forme de *Leaia*, la même *Estheria striata*, les mêmes poissons que l'on retrouve dans le Nord de la France et en Belgique, et aux mêmes niveaux, ainsi qu'il ressort des beaux travaux de M. X. Stainier sur la faune du terrain houiller de Belgique.

Les analogies avec la faune du terrain westphalien d'Angleterre sont tout aussi étroites. Elles se manifestent surtout nettement en ce qui concerne les insectes et les araignées dont les formes anglaises nous sont connues grâce aux excellents mémoires de MM. H. Bolton et R. Pocock. Sur les cinq espèces d'araignées citées dans ma liste, deux sont spéciales au terrain westphalien d'Angleterre et les autres en sont des formes extrêmement voisines. Parmi les insectes, le genre *Soomylacris* n'a été signalé jusqu'ici qu'en Angleterre et dans le Nord de la France. Les poissons sont identiques dans les deux régions. Quant aux lamellibranches, ils appartiennent à peu près tous à des espèces décrites récemment du terrain houiller de la Grande Bretagne par le Dr. W. Hind.

L'étude détaillée de ces fossiles nous confirme donc dans cette idée, séduisante à priori, que la faune du terrain westphalien de Belgique, d'Angleterre et du Nord de la France, à l'instar de la flore, est une et homogène et que ces dépôts houillers, aujourd'hui séparés par des limites politiques ou naturelles, se sont formés à la surface d'un même continent dans une même dépression marécageuse, où la vie était la même en les différents points à un moment donné.

Mais là où cette homogénéité devient plus surprenante, c'est quand on la voit s'étendre aux dépôts de même âge de l'Amérique du Nord. Il existe, en effet, une ressemblance profonde entre la faune continentale westphalienne du Nord de l'Europe et celle de l'Amérique Septentrionale. Je bornerai ma comparaison à dessein au bassin houiller du Nord de la France. Si incomplètes que soient encore nos connaissances sur la faune de ce bassin, il est certains faits qui dès maintenant sont dignes de retenir l'attention. En voici quelques-uns:

La *Leaia tricarinata* M. et W., signalée dans le bassin français est un fossile du terrain houiller de l'Illinois.[1] Je suis persuadé qu'il s'agit là de la même espèce. Elle est surtout abondante en Illinois, au niveau où on la trouve en France, dans la partie inférieure du westphalien.

Le *Prestwichia Danae* M. et W., du terrain houiller de l'Illinois, est connu dans le bassin du Nord de la France où il a été décrit sous le nom de *P. C[illegible]ini*, Boulay. Ici encore, l'identité spécifique ne fait aucun doute.

Le seul myriapode recueilli dans ce même bassin paraît très voisin d'une espèce américaine, *Eileticus aequalis*, Scudder, également du terrain houiller de l'Illinois.

Mais les termes de comparaison les plus frappants nous sont fournis par les insectes. Parmi les genres cités ci-dessus, il en est, tels que les *Orthomylacris*, *Necymylacris*, *Stenomylacris*, *Archimylacris*, qui ne sont connus que dans les terrains houillers de Pennsylvanie et de l'Illinois et sont cantonnés d'autre part sur l'ancien continent dans les bassins westphaliens de l'Angleterre et de la France septentrionale. Et si l'on réfléchit aux variations extrêmes qu'accusent les insectes houillers et au nombre important de genres et d'espèces que l'on a dû créer pour en classer les empreintes, on convient aisément que la présence d'insectes appartenant au même genre dans deux régions houillères différentes constitue une analogie aussi étroite que la présence d'une même espèce pour tout autre groupe du règne animal. Ces analogies dans la faune entomologique sont d'autant plus frappantes que, si l'on compare la faune d'insectes westphaliens d'Angleterre, de Belgique et du Nord de la France, à celles des bassins de Commentry et de la Saxe, si célèbres et si bien connues, mais, il est vrai, d'âge plus récent, on voit que, d'un côté et de l'autre, les genres qui les composent sont complètement différents.

Ainsi, bien que notre connaissance de la faune continentale du terrain houiller du Nord de la France soit encore assez sommaire, on ne peut pas ne pas enregistrer déjà ces ressemblances avec la même faune des bassins westphaliens et de l'Amérique du Nord et il est probable que dans l'avenir, avec le progrès des recherches, cette évidente parenté achèvera de se préciser.

Au cours de l'excursion A 1 de ce Congrès, l'examen des bassins houillers de Nouvelle-Ecosse n'a fait que confirmer pleinement ma manière de voir.

En résumé, on peut dire qu'il y a plus d'analogies entre les faunes houillères ayant habité l'hémisphère Nord, à la même époque westphalienne, dans des bassins paraliques où les conditions de dépôt étaient semblables, fussent-ils très éloignés géographiquement, qu'entre la faune de ces bassins et celle des lacs qui à l'époque stéphanienne, à quelques kilomètres des premiers, s'étendaient à l'intérieur des terres, comme ceux de Saxe ou de Commentry.

[1] Les paléontologistes européens désignent habituellement cette espèce sous le nom de *Leaia salteriana*, Jones. Je crois qu'elle diffère en réalité de la forme du carbonifère inférieur d'Ecosse par plusieurs détails importants que malheureusement la mauvaise figure de *L. Salteriana* (*Fossil Estheriæ*, Pal. Soc. Lond., pl. 1, fig. 21) donnée par R. Jones, ne permet guère d'apprécier en toute certitude. En tous cas, l'identité de la *Leaia*, trouvée par M. H. Bolton au toit de High vein du bassin de Bristol, et de celle qui fut recueillie dans le bassin français (veine No. 4 du Nord à Aniche) avec la *Leaia tricarinata* de l'Illinois ne paraît faire aucun doute. C'est pourquoi je préfère la rapporter à l'espèce bien définie de Meek et Worthen plutôt qu'à la forme de Jones, insuffisamment décrite et d'âge différent.

DISTRIBUTION STRATIGRAPHIQUE DE LA FAUNE CONTINENTALE DANS LE TERRAIN HOUILLER DU NORD DE LA FRANCE.

Examinons maintenant comment se répartissent les différentes espèces que j'ai citées, dans l'épaisseur du terrain houiller productif du Nord de la France.

Le fait qui frappe d'abord, à l'étude de cette faune, c'est que les niveaux de schistes à fossiles d'eau douce, complètement absents à la base du terrain houiller, deviennent, à mesure que l'on s'élève dans la série des couches westphaliennes, de plus en plus abondants. Le développement progressif et régulier de cette faune est visiblement en relation avec l'établissement d'un régime de plus en plus franchement continental qui remplacera peu à peu le régime marin du début de l'époque houillère. Insensiblement, à mesure que les invasions marines se raréfient, le nombre des lits à *Carbonicola* et *Anthracomya*, rares ou inconnus dans les 100 premiers mètres de l'étage, sous le grès d'Andenne, augmente jusqu'à ce que dans les zones supérieures, à Lens et à Bruay, ils forment d'importants dépôts de roches bitumineuses où les lamellibranches et les ostracodes pullulent.

Mais cette variation constitue un phénomène trop lent et progressif pour que le stratigraphe puisse se servir utilement dans la pratique des caractères qu'elle fournit. Il est nécessaire de s'attacher à reconnaître, non plus simplement la présence de fossiles d'eau douce, mais d'étudier la répartition des différentes espèces qu'on peut y distinguer.

Il est extrêmement rare, en effet, qu'une espèce traverse sans se modifier toute l'étendue des temps westphaliens. Je ne connais guère qu'un ostracode, *Carbonia fabulina*, et un poisson, *Cœlacanthus elegans*, que l'on retrouve identiques à la partie inférieure et au sommet du terrain houiller dans le Nord de la France. Les autres espèces ont eu une durée relativement courte, ce qui permet de leur fixer à chacune une place bien nette dans l'épaisseur des strates houillères. On peut donc distinguer dans ce terrain une série d'horizons fauniques, basés uniquement sur l'étude des animaux lacustres, terrestres ou aériens, et analogues aux zones que M. R. ZEILLER a tracées d'après la flore.

Ces faits sont résumés dans le tableau synchronique qui est joint à cette note; ils sont exposés en détail dans les lignes qui suivent en commençant par les niveaux les plus inférieurs.

Zone de Flines.— Il convient d'abord de mettre à part le niveau que nous appelons dans le bassin du Nord la zone de Flines et qui comprend les couches lés plus inférieures du Westphalien. La limite supérieure de cette zone est constituée par le grès d'Andenne, excellent repère lithologique. La zone de Flines est caractérisée par une flore pauvre à *Pecopteris aspera* (zone A_2 de M. ZEILLER), par l'abondance de niveaux marins et par la présence d'une riche faune marine à *Prolactus carbonarius* que M. CH. BARROIS[1] a

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[1] CH. BARROIS. *Étude des strates marines du terrain houiller du Nord*; 1ère part., Mém. topogr. souterr., 1912.

DISTRIBUTION COMPARÉE DE LA FLORE ET DE LA FAUNE DANS LE TERRAIN WESTPHALIEN DU NORD DE LA FRANCE.

Bassin houiller du Nord de la France. Zones végétales.	Bassin houiller du Nord de la France. Div. de M. ZEILLER	Divisions correspondantes du terrain houiller d'Angleterre.	Divisions correspondantes du terrain houiller de Belgique.	Bassin houiller du Nord de la France. Niveaux marins.	Bassin houiller du Nord de la France. Niveaux fauniques (faune continentale).	Bassin houiller du Nord de la France. Caractères paléozoologiques de ces niveaux.
Zone de Bruay à *Linopteris obliqua*.	C	Transition series	Assise des flénus de Mons.		Zone à *Anthracomya Phillipsii* et *Estheria Simoni*.	Abondance des schistes bitumineux à lamellibranches et entomostracés d'eau douce.
Zone de transition entre B et C.	B_3	(Ardwick series).	Assise de Charleroi		Zone à *Anthracomya Williamsoni*.	Les insectes sont cantonnés dans cette zone et celle qui la surmonte.
Zone à *Alethopteris Davreuxi*.	B_2	Bedminster series			Z. à *Anth. modiolaris*. S. z. à *Anthracomya pulchra*.	Au-dessus de ce niveau les *Carbonicola* deviennent très rares, de même que les poissons; les *Anthracomya* prennent au contraire un grand développement.
Zone à *Lonchopteris Bricei*.	B_1	(Middle C. M.)			S. z. à *Carbonicola similis*.	
Zone de Vicoigne à *Neuropteris Schlehani* et *Sphenopteris Hœninghausi*.	A_2	Aston series (Lower C. M.).	Assise du Châtelet.	— Niveau marin — à *Pleuroplax affinis* de la veine Bernard (Aniche). — Niveau marin — à *Productus scabriculus* de la veine Joubert (Aniche).	Zone à *Carbonicola aquilina* et *Leaia tricarinata*. Zone à *Carbonicola acuta* et *Estheria striata*.	Zone caractérisée par l'abondance des poissons et des *Carbonicola*; les *Anthracomya* y sont représentées par des individus rares et nains.
Grès d'Andenne.	A_1	Millstone grit.	H_1c	Grès à encrines.	Faune principalement marine, la faune continentale de ce niveau est mal connue.	
Zone de Flines à *Pecopteris aspera*.			H_1b (Assise de Namur).	Faune marine riche à *Productus carbonarius*.		
Zone à *Asteroc. scrobiculatus*.		Yoredale series.	H_1a (Assise de Chokier).	Ampelites de Baille à *Glyphioceras diadema*.		

récemment étudiée en détail et suivie à travers tout le bassin houiller. Ce niveau de Flines peut être également défini, en plus de ces caractères, par l'extrême rareté, sinon l'absence complète de niveaux à coquilles d'eaux douces et de fossiles franchement limniques.

Zone à Carbonicola acuta et Estheria striata.—Cet horizon se trouve immédiatement au-dessus du grès d'Andenne et, par conséquent, de la zone de Flines. On peut lui fixer comme limite supérieure le repère précis constitué par l'invasion marine à *Productus scabriculus* observable au toit de la veine Joubert d'Aniche (= passée de Lame).

Ainsi défini, ce niveau coïncide avec la moitié inférieure de la zone végétale A_2 de M. Zeiller (zone de Vicoigne à *Neuropteris Schlehani* et *Sphenopteris Hœninghausi*).

Il comprend la plupart des veines exploitées à Carvin, le faisceau compris entre les veines Désirée et Saint-Charles de Lens et Meurchin, entre les veines du Nord et Noël de Vicoigne, les veines voisines de la veine du Nord au centre de la concession d'Aniche, la veine Six-paumes et celles qui la surmontent à la fosse de Vieux-Condé (Anzin).

Les fossiles suivants sont caractéristiques de ce niveau:

Carbonicola acuta,
Estheria striata, var. *Tolcana,*
Catacanthus mucronatus,
Elonichthys, cf. *semistriatus,*
Mesolepis scalaris,
Cheirodus granulosus.

D'autres fossiles, sans être localisés dans cette zone, y sont extrêmement fréquents:

Anthracomya minima,
Naiadites carinata,
" *modiolaris,*
Rhizodopsis sauroides,
Calacanthus elegans,
Rhadinichthys monensis.

Carbonicola acuta paraît surtout abondante à la partie inférieure de cette zone, aussi bien en France qu'en Belgique (veine Léopold de Charleroi). Il est à remarquer que dans tous les bassins d'Angleterre cette espèce, associée à *C. robusta*, est également localisée à la base des Lower Coal Measures, immédiatement au-dessus du Millstone grit.

C'est dans cette zone que l'on a recueilli à Vicoigne un myriapode (*Eileticus,* cf. *æqualis*) et à Meurchin un xyphosure (*Belinurus regina*).

La faune de ce niveau doit sa physionomie toute spéciale, non seulement à la présence d'espèces particulières de lamellibranches et de crustacés, mais surtout à l'extrême abondance et à la *variété des poissons*. La faune ichthyologique est bien plus riche en individus et en espèces à ce niveau que dans la zone de Flines. Le même fait se vérifie en Belgique où les observations si précises de M. X. STAINIER[1] dans le bassin de Charleroi mettent en évidence que les lits à écailles de poissons sont à ce même niveau (faisceau du Châtelet) plus abondants que partout ailleurs.

Zone à Carbonicola aquilina et Leaia tricarinata.—Un deuxième horizon faunique peut être distingué dans la série de strates du bassin de Valenciennes qui sont comprises entre le niveau marin à *Productus scabriculus* et le niveau marin à *Pleuroplax affinis* (veine Bernard d'Aniche). Les documents réunis à l'heure actuelle ne permettent pas de fixer exactement la position de cette zone dans le bassin du Pas-de-Calais.

Elle correspond ainsi à la moitié supérieure de la zone végétale A_2.

On trouve à ce niveau:

Carbonicola aquilina,
Carbonicola turgida,
Naiadites modiolaris,
Naiadites carinata,
Naiadites quadrata,
Anthracomya modiolaris,
Anthracomya minima,
Leaia tricarinata,
Rhadinichthys monensis,
Strepsodus sauroides,
Rhizodopsis sauroides.

Dans cette zone, *Leaia tricarinata* est absolument localisée au niveau de la veine No. 4 du Nord à Aniche. Ce fossile présente, dans le bassin houiller de Belgique, les mêmes caractères de localisation au même niveau.[2]

Les poissons que l'on rencontre encore assez fréquemment à la base de la zone, y sont moins variés que dans la précédente et deviennent, à mesure que l'on s'élève, extrêmement clairsemés. La faune ichthyologique, si développée à la base du terrain houiller et surtout dans les couches immédiatement supérieures au grès d'Andenne, ne sera plus désormais représentée dans les couches plus récentes que par de rares empreintes très disséminées.

Zone à Anthracomya modiolaris.—La faune des deux zones précédentes où les *Carbonicola* sont parmi les formes les plus communes, est peu à peu remplacée par un ensemble d'espèces bien différentes qui constitue la zone plus élevée à *Anthracomya modiolaris.*

On peut recueillir cette faune dans les couches situées entre le niveau marin de veine Bernard à Aniche et les veines les plus supérieures de cette concession. Dans le bassin du Pas-de-Calais, à Lens par exemple, elle se trouve au sommet du faisceau de la veine Six-sillons et à la base du faisceau de la veine Ernestine.

Cette zone correspond donc à peu près aux zones végétales B_1 et B_2 de M. ZEILLER à *Lonchopteris Bricei* et *Alethopteris Davreuxi.*

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[1] X. STAINIER. *Stratigraphie du bassin houiller de Charleroi et de la Basse-Sambre*; Bull. Soc. belge Géologie, T. LXXV, p. (mém.) 1 et pl. I, 1901.

[2] X. STAINIER. Ann. Soc. géol. de Belgique, T. XXXIII, p. B. 80.

L'*Anthracomya modiolaris* est abondante dans toute cette partie du terrain houiller. C'est un des éléments les plus communs de cette faune qui comprend les espèces suivantes:

Carbonicola similis,
Anthracomya modiolaris,
" *minima*,
" *Williamsoni*, forme *pulchra*,
Naiadites carinata,
" *modiolaris*,
Carbonia scalpellus.

On peut établir dans l'ensemble deux subdivisions:

1. Un niveau inférieur où *Carbonicola similis* abonde, par exemple, dans les veines voisines de la veine des Boers d'Aniche.

2. Un niveau supérieur où l'on trouve surtout l'association des lamellibranches suivants:

Anthracomya Williamsoni, forme *pulchra*,
Naiadites carinata.

et qui est limité à la veine Bernicourt et aux veines qui lui sont supérieures à Aniche.

Ce second niveau me paraît correspondre à celui du Burnwood or Little Mine ironstone du bassin du North Staffordshire, où abonde et est localisée *Anthracomya pulchra* associée à *Anthracomya Adamsi*, Salter, belle espèce que nous n'avons pu encore recueillir en France.

Zone à Anthracomya Williamsoni.—Elle comprend dans le bassin du Pas-de-Calais le sommet du faisceau de veine Ernestine, jusqu'à la veine Arago de Lens. Cette zone paraît exister dans le bassin houiller du Nord et y être représentée par les veines supérieures de la fosse Cuvinot d'Anzin.

Elle correspond à la zone végétale B_3 de M. ZEILLER et surtout à la partie supérieure de cette zone.

Au point de vue qui nous occupe, elle est caractérisée par la présence d'une espèce d'*Anthracomya* très reconnaissable: *A. Williamsoni*, dont on trouve de beaux exemplaires en particulier au toit de la veine Arago à Liévin et de la première passée au-dessus de veine Julie à Lens. Cette espèce, qui, d'après M. W. HIND, apparait plus bas dans le Westphalien d'Angleterre, n'a jamais été trouvée chez nous dans les zones inférieures à celle-ci, tout au moins sous sa forme typique, l'*Anthracomya pulchra* de la zone précédente en étant, pensons-nous, une variété naine.

Dans la zone à *A. Williamsoni*, les lits à fossiles d'eaux douces sont relativement peu abondants et la faune en est encore mal connue. On y voit apparaître, *à l'état de raretés*, deux espèces qui prendront dans la zone suivante un développement caractéristique, *Estheria Simoni* et *Anthracomya Phillipsii*.

Zone à Anthracomya Phillipsii.—Cette zone comprend le faisceau des veines les plus élevées du bassin du Nord de la France, faisceau qui commence à la veine Arago de Lens et aux environs de 21ème veine de Bruay. Elle correspond assez bien à la zone végétale C à *Linopteris obliqua* et est caractérisée par les fossiles suivants:

Anthracomya Phillipsii, très abondantes,
Carbonia fabulina, " "
" *Rankiniana*,
Cypridina striata,
Estheria Simoni,
Estheriella Reumauxi,
Prestwichia Danæ.

On y a trouvé, dans la veine St. Jules de Bruay, des débris de poissons appartenant au *Cœlacanthus elegans*.

Ce niveau est surtout bien reconnaissable parce qu'il renferme de nombreux lits de schistes bitumineux absolument pétris d'*Anthracomya Phillipsii*, associées à *Carbonia fabulina*. Il correspond parfaitement aux couches dans lesquelles, en Angleterre, l'*Anthracomya Phillipsii* prend un développement analogue.

Ce sont les schistes de cette zone et de la précédente qui ont fourni la totalité des empreintes d'insectes recueillies dans le bassin du Pas-de-Calais (à une seule exception près). En particulier, la veine Alfred de Liévin a livré un grand nombre de Blattoïdes. La même localisation des insectes dans les couches récentes du Westphalien s'observe aussi en Belgique et en Angleterre.

Ainsi, parmi toutes ces variations de la faune continentale, c'est l'évolution des lamellibranches qui nous fournit les meilleurs repères stratigraphiques dans le bassin houiller du Nord de la France. Il est fort intéressant de comparer ces résultats à ceux qu'a obtenus M. W. Hind pour les bassins anglais et de constater que, dans ses grands traits et même dans certains de ses détails, la distribution des *Anthracomya* et des *Carbonicola* est la même en l'un et l'autre pays.

L'étude de la faune continentale est donc susceptible de donner des renseignements stratigraphiques aussi précis que celle de la flore. On peut aisément fixer, en déterminant les espèces animales recueillies dans un niveau de schistes, avec une approximation satisfaisante, la position de ce niveau dans l'échelle stratigraphique que nous avons dressée. Et comme ces fossiles sont très répandus dans les sédiments houillers, on est souvent appelé à utiliser les caractères paléontologiques qu'ils donnent à ces sédiments.

En certains cas particuliers la précision des repères paléontologiques peut être encore singulièrement accrue. Il arrive en effet qu'une espèce prend un développement très grand à un niveau bien déterminé et n'est plus connue à aucun autre niveau, si ce n'est à l'état d'empreintes rares et isolées. On conçoit que des observations de ce genre soient susceptibles de donner au stratigraphe les meilleurs repères qu'il puisse désirer.

C'est ainsi que les ingénieurs de Lens et Liévin reconnaissent la veine Beaumont parce que le schiste de son toit contient en grande abondance *Estheria*

Simoni, à l'exclusion de tout autre fossile. Au moyen de ce caractère, on a pu identifier en toute certitude à la veine Beaumont, les veines Ste. Barbe de Béthune, Marie de Courrières, St. Jérome de Nœux, au toit desquelles pullule la même *Estheria*.

La localisation de *Leaia tricarinata* au toit de Veine No. 4 du Nord à Aniche, à peu près au même niveau où on la trouve en Belgique, constitue un repère du même ordre.

De même, *anthracomya pulchra* n'est guère connue qu'au toit de la veine Bernicourt d'Aniche (veine No. 6 de l'Escarpelle), au niveau où elle est également cantonnée dans le terrain Westphalien d'Angleterre, tandis que *Carbonicola similis* caractérise les couches voisines de veine des Boers à Aniche et permet de leur assimiler le faisceau de veine Elisa de Leus où elle est très répandue.

Quant à *Carbonicola acuta*, c'est la première espèce de lamellibranche limnique qui se soit développée dans notre bassin houiller, aussi bien en France qu'en Belgique, aussitôt après la période de vie marine de la zone de Flines. Il est fort curieux de constater qu'il en est de même en Angleterre et que cette espèce a habité aussi les premières lagunes saumâtres qui ont succédé aux eaux marines du Millstone grit.

L'étude et la recherche des représentants de la faune continentale dans le terrain houiller a donc, non seulement un intérêt paléontologique théorique, mais est aussi susceptible de fournir au stratigraphe et au mineur de précieux documents sur la position relative des strates houillères, au moins au même titre que la connaissance des espèces végétales.

Les quelques résultats généraux résumés dans cette note en font foi, malgré leurs caractères sommaires.

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THE AGE OF THE NUBIAN SANDSTONE.

BY

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The Nubian sandstone occurs in Nubia, Egypt, Sinai, Arabia and Syria, including Palestine. It has furnished the stone for Karnak and other Egyptian temples and in it are carved the celebrated rock tombs of Petra. Its upper limit in time is well defined, as it is everywhere bounded above by Cretaceous limestone of Turonian age, with which it is conformable. Its lower limit in time is not so easily defined. In Nubia, Egypt, Arabia, and parts of Sinai, it rests unconformably upon crystalline rocks. In middle Syria, i.e., in the region of Lebanon, Anti-Lebanon and Hermon, it rests conformably upon Jurassic limestone of Corallian age, and in this region is referred in its entirety to the Cenomanian. At Wâdi-Nasb in western Sinai we find, in descending order:

(*a*) Turonian limestone,

(*b*) sandstone, the so-called Nubian sandstone,

(*c*) limestone of Lower Carboniferous age, containing characteristic corals, crinoids, and brachiopods,

(*d*) sandstone, the so-called Desert sandstone. These are apparently conformable with each other and rest unconformably upon

(*e*) crystalline rocks.

At al-Ubrush, just above al-Ghaur us-Sâfiyeh, southeast of the Dead sea, a very similar series was discovered by Professor Edward Hull:

(*a*) Turonian limestone, with abundant fossils,

(*b*) grey sandstone,

(*c*) red sandstone,

(*d*) shale,

(*e*) limestone (Middle Cambrian),

(*f*) red sandstone. These formations are apparently conformable with each other and rest unconformably upon

(*g*) coarse, dark-coloured conglomerate, which in turn rests unconformably on

(*h*) crystalline rocks.

Professor Hull was inclined to think that the limestone (*e*) was Carboniferous, on account of the similarity of its stratigraphical relations to those of the Wâdi-Nasb limestone, both being sandwiched between two sandstones, with Cretaceous limestone above the upper sandstone and crystalline rocks below the lower sandstone. Professor Hull was unable to collect fossils from this limestone and did not assert positively that it was of Carboniferous age. More recently Professor Max Blanckenhorn has announced that the limestone (*e*) of al-Ubrush is of Middle Cambrian age collections made by him having yielded fragments of *Paradoxides* and other trilobites and brachiopods. It follows of course that the underlying sandstone and conglomerate are older than Middle Cambrian, just as at Wâdi-Nasb the underlying sandstone must be older than Lower Carboniferous.

In the region of Lebanon, Anti-Lebanon and Hermon the Corallian limestone, which underlies the Nubian sandstone, is the oldest formation exposed. In northern Syria and in the southern part of Asia Minor there is no sign of anything corresponding to the Nubian sandstone, and for the most part the Cretaceous and Tertiary limestones rest directly upon the crystalline rocks, there being in that region no rocks of intermediate age, with the exception of comparatively small outcrops of Devonian and Triassic limestones. On the southern shore of Lake Van, in eastern Asia Minor, sandstone has been reported which may possibly prove to be equivalent to the Nubian sandstone.

We have seen that in Lebanon the age of the Nubian sandstone is well defined, as it is bounded above by Upper Cretaceous limestone, and below by Jurassic limestone, with both of which it is conformable. In its higher strata it contains Cenomanian fossils. Lower down are thin beds of coal with shale and clay, and its lowest portions are without fossils.

Dr. W. F. Hume, Director of the Geological Survey of Egypt, informs me that at Wâdi-Kana, in eastern Egypt, the lower part of the Nubian sandstone is non-fossiliferous, but the upper part contains Cenomanian fossils. Above this there is a series in which sandstones alternate with Turonian and Senonian limestones and clays. Farther south the Nubian sandstone extends upward to phosphate beds belonging to the Campanian division of the Senonian.

The apparent conformity with the Carboniferous of Wâdi-Nasb and the Cambrian of al-Ubrush suggests that the Nubian sandstone is continuous from those early times up to the Cretaceous. This, however, seems impossible in view of the great length of time involved, and we are driven to suppose that it contains one or more unconformities which may still be discovered. The sandstones which are immediately above and below the Cambrian limestone and shale of al-Ubrush are undoubtedly conformable with them, and the same is true of the Carboniferous at Wâdi-Nasb. We should therefore look for unconformity somewhere higher up in the Nubian sandstone. It is at least clear that, from Nubia as far north as the Dead sea, terrestrial or shallow-water conditions have prevailed from the Pre-Cambrian to the Cretaceous, except during the times of deposition of the limestones of al-Ubrush and Wâdi-Nasb, which may be looked upon as indicating transgressions of the Mediterranean in Middle Cambrian and Lower Carboniferous times respectively.

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CERTAIN FEATURES OF EOLIC GRADATION.

BY

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So customary is it to regard the general slopes of land surfaces as determined by the grading capacity of the principal streams that no provision is made for any possible deviation or modification of this accepted scheme. In all problems of general, or regional, gradation the influences of a humid climate alone are considered. A general grade-plain or, in its ultimate expression, a peneplain is conceived to extend more or less uniformly from the piedmont belt to the strand line of the nearest ocean. On a smaller scale the two opposed slopes of an intermont valley are described as reaching from the mountain foot down to the nethermost central line, or to the bed of the master drainage way. All grading effects are regarded as proceeding from higher to lower levels, for transportation of rock-waste by means of running water is in its nature necessarily gravitational.

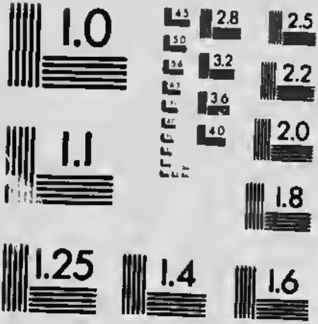
On the same moist-climate hypothesis are usually explained the formation of the smooth and notably sloping intermont plains of many desert regions, and their attendant peculiarities of relief. It is the main purpose of the present communication to offer some evidences in support of an alternative thesis, to ascribe desert planation mainly to wind-action, to advocate the improbability of so high a gradient as the desert plains often possess being a water-grade, and to point out reasons for believing that the gradation of such plains takes place chiefly not down-stream but up-hill.

Notwithstanding the fact that in such regions as the Great basin and the Mexican tableland, for example, the descriptions of the topographic features and the explanations of their origin are numerous and often elaborate, none of these explanations have ever been very satisfactory. They seem to lack something of the critical benefits of that unconscious encouragement which long residence in a region lends to the formulation of adequate hypotheses, and which greater familiarity with other conditions during fleeting sojourn invariably tends to withhold. It appears that any explanation could hardly be otherwise than insufficient when it is advanced strictly on a basis of water erosion.

As is well known, the arid regions of western North America present mainly a close-patterned type of orogenic structure. They present innumerable short, narrow, and usually lofty mountain ranges separated by wide smooth valleys. Captain Dutton has likened the appearance of these ranges on the map to an army of caterpillars crawling northward out of

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



Mexico. The remarkable rock floors of many of the intermont plains are a distinctive feature that has been the subject of wide discussion and of prolix description, especially by Messrs. McGee, Hershey, Baker, Davis and others. The peculiarities which they present appear clearly to indicate that they are areas of rapid degradation instead of prodigious aggradation, as has been quite generally claimed.

One of the most notable and heretofore inexplicable features of the desert intermont plains is their exceedingly high gradient. It is a slope too steep for ordinary railway trains easily to climb. It is seldom less than two per cent.; sometimes it reaches four per cent., that is, 100 to 200 feet rise in the mile. When it is recalled that the channel grade of many large streams, as the Mississippi and Missouri rivers, is only a few inches to the mile, and that a grade of a few feet to the mile produces a mountain torrent, the conclusion is inevitable that the much steeper slope of the smooth desert plains can hardly be a phenomenon of desert water gradation.

The rock floor and the smooth surface of the intermont valleys have been accounted for by W. J. McGee, on the hypothesis of sheet-flood erosion, occasioned during desert storms by violent sporadic down-pours that planed off the inequalities of the surface. Later observations show that the sheet-flood is a result of the even relief and not a cause of it, and that its general effect as an erosional force is almost *nil*.

The original description and definition of sheet-flood erosion is not what the dwellers of the desert call by that title, but arroyo-running. As already intimated the chief reason why the run-off of storm waters in desert regions flows down the inclined plains surface in broad thin sheets—sheet-floods—rather than in narrow channels as it does in humid lands, is that the plains are already prepared as such for the local flood waters. The plains were there long before the waters came. The moving sheet waters do not form the plains. The corrading effects of running water are the same in desert country as they are in moist regions. The main difference lies in the fact that copious rainfall in an arid area is far less frequent than in a humid land. Probably on an average a given locality does not have sufficiently heavy precipitation to form a sheet-flood oftener than once in a dozen years. The gradients of the intermont plains are all ample for the most effective normal work by water. Nevertheless, the plains-surface remains uncorraded by the sporadic storm waters because all inroads of ordinary water-action on it are quickly filled up "between showers" and smoothed over by the drifting, wind-blown sands and soils. A freshet gully may last a day or a week, and is then smoothed over and obliterated. Another may not be formed in the neighbourhood for a thousand weeks. To the casual observer water action on the desert is not normal because its corrading effects are immediately and completely counteracted by the more powerful and constant wind effects.

That an extensive plain in which the ruling grade is more than two per cent. cannot possibly be, even in the desert, a water-formed slope is supported by a number of facts. Moreover, it is capable of being experimentally tested. Were the leveling tendencies of the winds wholly absent from the desert region it is quite probable that the corrasive effects of what desert waters there are would be much the same as they are in humid lands, differing only in degree. This is well shown in cases where wing-dams have been constructed to protect lines of railway from the flood-sheet and the latter has come before the earthworks have had time to be leveled by the winds. In one instance in particular a culvert and track were washed out in less than an hour's time, and a canyon 75 feet deep, 50 feet wide, and several miles long was excavated in the smooth surface of the sloping plain. By the time a permanent bridge was built to span the deep trench the winds had filled the entire excavation, so that the place where a yawning chasm had been was as smooth as the rest of the plain, and the wing-dams also had melted down into the general smoothness of the desert's surface. For several years, until it was finally replaced by an earthen grade, travellers were wont to express great wonder at the possible utility of a fine steel bridge resting on the smooth sands of the desert plain.

Another pertinent case is that of the Socorro arroyo in central New Mexico. There is water running in this shallow wash once or twice a year, the supply coming off the lofty Magdalena peaks 20 miles away. For many years this arroyo, which divides the town of the same name, has given the townsmen an infinite amount of trouble. That its two per cent. grade really produces torrential conditions when the waters do run is indicated by the fact that the arroyo-bed is composed largely of pebbles and boulders, many of the latter attaining a diameter of two feet. In order to obviate the frequent inconveniences it was determined, a few years ago, to divert the channel four miles above the town. This change of course was accomplished by cutting a narrow trench from the arroyo-bed through its bank to a point some 50 yards to one side, where the general plain was slightly lower than the bed of the wash at the head of the ditch. A low dam was thrown up obliquely across the arroyo by piling up boulders in the bed. It was anticipated that the first water coming down the wash would flow through the ditch or spill-way and soon cut a deep channel, and that eventually this would carry away all the flood-water. Results more than fulfilled expectations: the first time the dry creek became a brook there was cut along the trench in a single night a chasm 50 feet deep for more than a mile down the slope of the plain. The materials from this great artificial canyon spread out over the railway three miles away to a depth of seven feet and to a width of half a mile, necessitating its reconstruction and the raising of its grade for a distance of several miles.

These two illustrations could be multiplied indefinitely. They merely prove beyond all question that the law of running water is the same in the desert as it is in humid lands. If the waters were actually present in the arid regions they would gather into ramifying stream systems in the same way that they do in other parts of the world. Because they are so scant their general erosion powers become almost negligible factors.

As shown elsewhere the planorasive effects in arid regions are directly attributable to wind work rather than to stream corrasion. Viewed from this angle the consideration of desert landscape features is put on a basis entirely different from that usually adopted.

On the basis of an origin through means of stream corrasion, as under the influences of a humid climate, it has been the custom to regard the intermont basins as areas of vast aggradation from débris brought down from the desert ranges. The steeper slopes of the piedmont are designated by the Spanish-speaking inhabitants of the northern Mexican tableland as the bajada belt. On the general assumption that all the intermont valleys are filling up by the transference of mountain waste from the high peripheries, some physiographers have lately extended the meaning of the term bajada to cover all the plains slopes, as opposed to the central level area, or playa, which sometimes characterizes the valleys.

In western United States the arid regions are peculiarly constructed. As is well known there is no marked alternation of resistant and weak strata. Hard rocks are segregated to a thickness of more than 10,000 feet at the bottom of the geologic column and above the Azoic complex; the soft beds are collected in equal thickness at the top. In the profound faulting and folding which the region has undergone, in Tertiary times chiefly, the indurated rocks are brought into juxtaposition with the soft ones.

Under these conditions any method of vigorous general leveling and lowering of the country would first produce strong contrasts of relief. To attain these results it is not even necessary to postulate the immediate dislocative conditions which the basin-range theory of mountain structure demands. It is worthy of note, to emphasize the fact that the mountain blocks are subject to two kinds of erosional attack. There is the minor effect of stream action, apparently producing normal dissection, which has attracted widest attention; and there is the major effect of eolic erosion which works into the sides of the orographic blocks, producing a remarkable shelf all around at the constantly lowering level of the piedmont plain and which is the counterpart of the plain of marine erosion that Ramsey, in the middle of the last century, so strenuously advocated for the British Isles.

In this connection it is unnecessary to point out or explain in detail that the locations of the orogenic fault-lines is not usually along the present scarps of the piedmonts, but far out on the plains; that there is a general absence of thick permanent wash accumulations at the foot of the mountains; that the meeting of two opposing slopes in the centre of the intermont valley seldom gives rise to master, longitudinal water-ways; that there is a general absence of distinct drainage lines on the surface of the bolsons; that the remarkable smoothness is presented by the foundation of the plains surface itself; or that the high inclination of the plains surface cannot possibly be the result of any known phase of running water. On the basis of water action there has never been any satisfactory explanation offered for any of these phenomena. Eolative influences, however, appear to account adequately for them all.

Dr. J. E. Spurr gives the most explicit account of the sweeping of strong winds successively up and down, across and obliquely over the intermont plains of the Great Basin region, carrying before them dense clouds of sand and dust. Nowhere are the winds uniformly vigorous throughout the bolsons. Their activities are reduced greatly on the lee side of mountains. Their strength materially increases as they recede from the near range, and is greatest against the exposed side of the far range. The medial portion of the bolson receives nearly the full force of the winds oftenest because it is exposed to their unobstructed sweep from all directions.

Elsewhere I have called attention to the locus of maximum lateral deflation as the line where desert mountain meets desert plain. Under ordinary conditions we also expect the locus of maximum lowering to be the middle of the broad bolsons. According to this recognition of conditions, eolic erosion necessarily operates from the lower to the higher elevation. As shown by Professor DAVIS, the winds in their action are not like water dependent on the gradient of the land surface for their gravitational acceleration; they may blow violently and work effectively on a perfectly level surface. Unlike water also they may erode vigorously uphill; and this is exactly what they manifestly and constantly do on the bolson plains.

Although wind erosion operates both down and up the slope, there is, owing to the peculiar configuration of each basin-shaped tract, a preponderance of effect on the up-slope part of the course. There appears to be a limit to the gradient on which the wind is able to blow sands extensively up-hill and this limit seems to lie chiefly between a two and a four per cent. gradient. It is for this reason, seemingly, that the intermont plains are so smooth, so uniform in grade, so high in gradient. Eolic gradation thus mainly wor[illegible] from a lower to a higher level. The direction of movement is directly op[illegible]site to that of stream gradation.

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SOCIÉTÉS GÉOLOGIQUES, SERVICES GÉOLOGIQUES ET SOCIÉTÉS MINIÈRES.

La liste suivante de sociétés géologiques, services géologiques et sociétés minières a été soigneusement compilée par le Secrétaire du Comité executif, M. W. S. Lecky, de nombreuses sources et avec l'aide de personnes et publications dont la liste serait trop longue à énumérer. Il adresse ses vifs remerciements a tous ceux qui ont bien voulu prêter leur concours a cette oeuvre.

Pour toute facilité cette liste est divisée en trois parties comme suit:

1. Sociétés géologiques.
2. Services géologiques.
3. Sociétés minières.

On remarquera que seules les sociétés qui s'occupent exclusivement de la géologie ou d'une branche quelconque de cette science sont comprises dans la liste des sociétés géologiques. Les nombreuses sociétés scientifiques ou d'histoire naturelle qui s'interessent à la géologie n'y sont pas comprises.

Dans la liste des services géologiques, on trouvera toutefois les noms et adresses de tous les services des gouvernements qui se chargent d'un travail géologique quelconque, quoique dans un certain nombre de cas, ce travail ne constitue qu'une partie des attributions de ces services.

On espère que le prochain Congrès aura à sa charge la publication d'une nouvelle édition de cette liste contenant les détails du travail, de l'organisation et des membres des diverses sociétés.

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Les Sociétés suivantes se livrent exclusivement à la géologie ou à quelque branche de cette science:

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Bonn.	Niederrheinischer Geologischer Verein, Geologisches Institut, Nussallee 2.
Coburg.	Verein für Geologie und Palaeontologie des Herzogtums Coburg und Meininger Oberlandes, Veste Coburg.
Frankfurt-am-Main.	Geologische Vereinigung, Viktoria Allee 7.
Freiberg, Sa.	Freiberger Geologische Gesellschaft.
Greifswald.	Palaeontologische Gesellschaft.
Hannover.	Niedersächsischer Geologischer Verein, Sophienstrasse 1.
Jena.	Deutsche Mineralogische Gesellschaft, Prof. Dr. G. Linck.
Jena.	Jenaer Gesellschaft für Mineralogie und Geologie, Mineralogisches Institut der Universität, Schillerstrasse 12.
Karlsruhe.	Oberrheinischer Geologischer Verein.

LEIPZIG.	Mineralogisch-Geologische Gesellschaft.
NÜRNBERG.	Geologische Gesellschaft.
STASSFURT.	Verband für Wissenschaftliche Erforschung der Deutschen Kalisalzlagerstätten.

AUTRICHE-HONGRIE.

ÖSTERREICH.	
WIEN, I.	Geologische Gesellschaft in Wien, Geologisches Institut der Universität.
WIEN, I.	Wiener Mineralogische Gesellschaft, Universität.
UNGARN.	
BUDAPEST, VII.	Magyarhoni Foldtani Társulat, Stefánia út. 11.

BELGIQUE.

ARLON.	Société géologique de Luxembourg, 59 rue St. Jean.
BRUXELLES.	Société belge de Géologie, de Paléontologie et d'Hydrologie, 19 rue Tasson Snel.
CHARLEROI.	Société paléontologique et archéologique, Boulevard de l'Ouest.
LIÈGE.	Société géologique de Belgique, 7 place de l'Université.

DANEMARK.

KÖBENHAVN.	Dansk geologisk Forening, Östervoldgade 7.

ÉTATS-UNIS D'AMÉRIQUE.

BERKELEY, CAL.	Le Conte Geological Club, University of California.
NEW YORK.	Geological Society of America, American Museum of Natural History.
PHILADELPHIA, PA.	The Philadelphia Mineralogical Society, Wagner Free Institute of Science, 17th and Montgomery Ave.
WASHINGTON, D.C.	Geological Society of Washington, U.S. Geological Survey.
WASHINGTON, D.C.	Paleontological Society. Secretary, Dr. R. S. BASSLER, U.S. National Museum.

FRANCE.

LE HAVRE.	Société géologique de Normandie, Musée d'Histoire naturelle.
LILLE.	Société géologique du Nord, 159 rue Brûle-Maison.
PARIS.	Société française de Minéralogie, Laboratoire de minéralogie de la faculté des sciences, Sorbonne.
PARIS.	Société géologique de France, 28 rue Serpente.

ILES BRITANNIQUES.

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DUDLEY.	Midland Geological Society.
HALIFAX.	Yorkshire Geological Society, Secretary, J. H. HOWARTH, Holly Bank, Skircoat Road, Halifax.
HULL.	Hull Geological Society, Shakespeare Hall.
LEEDS.	Leeds Geological Association, Law Institute.
LIVERPOOL.	Liverpool Geological Society, Royal Institution.
LONDON, W.	Geological Society of London, Burlington House, Piccadilly.
LONDON, W.C.	Geologists' Association, University College, Gower Street.
LONDON, S.W.	Mineralogical Society of Great Britain and Ireland. Secretary, Dr. G. T. PRIOR, British Museum (Natural History), Cromwell Road.
LONDON, S.W.	Palæontographical Society. Care of Dr. A. S. WOODWARD, British Museum (Natural History), Cromwell Road.
PENZANCE.	Royal Geological Society of Cornwall.
ÉCOSSE.	
EDINBURGH.	The Edinburgh Geological Society, 1 India Buildings, George IV Bridge.
GLASGOW.	The Geological Society of Glasgow, 207 Bath Street.

ITALIE.

ROMA. Società Geologica Italiana, Via Sta. Susanna, 13.

JAPON.

TOKYO. Chigaku Kyokai (Geological Society of Japan), Nishi-Konyacho, Kyobashiku.

MEXIQUE.

MEXICO, D.F. Sociedad Geológica Mexicana, 6a. del Ciprés 176.

NORVÈGE.

KRISTIANIA. Norsk Geologisk Forening.

EMPIRE RUSSE.

RUSSIE.
ST.-PÉTERSBOURG. Imperatorskoje Mineralogicesoje obscestvo. Secrétaire, M. F. N. CERNYSEV, Institut des Mines.
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FINLANDE.
HELSINGFORS. Geologiska Föreningen, Nikolaigatan, 5.

SERBIE.

BELGRADE. Société géologique de Serbie (Srpsko geolosko Drustva), Université, Institut géologique.

SUÈDE.

LUND. Geologiska Fältklubber.
STOCKHOLM. Geologiska Föreningen, Mäster Samuelsgatan 44.
UPSALA. Geologiska Sektionen of Naturvetenskapliga Student-Sällskapet.

SUISSE.

BERN. Société paléontologique suisse.
SOLEURE. Société géologique suisse (Schweizerische geologische Gesellschaft), M. le professeur Dr. KUNZLI.

UNION SUD-AFRICAINE.

TRANSVAAL.
JOHANNESBURG. Geological Society of South Africa, P.O. Box 1071.

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Les noms et les adresses des Services géologiques ou autres départements qui se livrent à des travaux de géologie, des divers gouvernements, sont consignés dans la liste suivante:

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BADEN. Grossherzogl. Badische Geologische Landesanstalt, Bismarckstrasse 7, Freiburg.
BAYERN. Geognostische Abteilung des Kgl. Bayer. Oberbergamtes, Ludwigstrasse 16, München.
ELSASS. Geologische Landesanstalt von Elsass-Lothringen, Blessigstrasse 1, Strassburg.
HESSEN. Grossherzoglich Hessische Geologische Landesanstalt, Paradeplatz 4 B, Darmstadt.
MECKLENBURG. Grossherzogl. Mecklenburgische Geologische Landesanstalt, Neues Museumsgebäude, Rostock.

Oldenburg. — Geologische Landesaufnahme Oldenburgs, Oldenburg.
Sachsen. — Königlich Sachsische Geologische Landesanstalt, Talstrasse 35, Leipzig.
Würtemberg. — Geologische Abteilung des Kön. Würtembergischen Statistischen Landesamtes, Büchsenstrasse, Stuttgart.

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Khartoum. — Geological Survey of the Anglo-Egyptian Sudan.

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RÉPUBLIQUE ARGENTINE.

Division de Minas, Geologia é Hidrologia, Calle Maipú 1211, Buenos Aires

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Tasmania. — Geological Survey of Tasmania, Department of Mines, Launceston.
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West Australia. — Geological Survey of West Australia, Beaufort Street, Perth.

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Österreich. — K. K. Geologische Reichsanstalt, Rasumoffskygasse 23, Wien, III/2.
Bosnien. — Bosnisch-Herzegowinische Geologische Landesanstalt, Sarajewo.
Kroatien. — Geologische Kommission für Kroatien-Slavonien, Agram (Zagreb).
Ungarn. — Magyar kiralyi földtani intézet, VII Stefánia út. 14, Budapest.

BELGIQUE.

Commission géologique de Belgique, Palais du Cinquantenaire, Bruxelles.
Service géologique de Belgique, Palais du Cinquantenaire, Bruxelles.

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Brésil. — Serviço geologico è mineralogico do Brasil, Rua Quitanda 49, Rio de Janeiro.
São Paulo. — Commissão geographica é geologica do Estado São Paulo, São Paulo.

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Service géologique, Ministère du Commerce et de l'Agriculture, Sophia

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Canada. — Geological Survey, Department of Mines, Ottawa.
Ontario. — Bureau of Mines, Department of Lands, Forests and Mines, Toronto.
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CEYLAN.

Mineralogical Survey of Ceylon, The Museum, Colombo.

CHILE.

Santiago. Instituto geológico de la Universidad de C le, Santiago.
Inspeccion de Geografia y Minas del Ministerio de Industrias y Obras Publicas Santiago.

CHINE.

China. Board of Mines, Department of Agriculture, Peking.
Quang Si. Geologist to the Government of the Province of Kwang Si, Wuchow.

DANEMARK.

Danmark. Danmarks geologiske Undersøgelse, Gammelmont 14, København.
Grönland. Kommissionen for Ledelsen af de Geologiske og Geografiske Undersøgelser i Grønland, Sokortarkivet, København.

ÉGYPTE.

Egypt. Geological Survey of Egypt, Dawawine Post Office, Cairo.

ESPAGNE.

Instituto geologico de España, Plaza de Los Mostenses 2, Madrid.

ÉTATS MALAIS FÉDÉRÉS.

Geological Department of the Government of the Federated Malay States, Kuala Lumpur.

ÉTATS-UNIS D'AMÉRIQUE.

United States of America. United States Geological Survey, Washington, D.C.
Alabama. Geological Survey of Alabama, University.
Arizona. Geological Survey of Arizona, Tucson.
Arkansas. Geological Survey of Arkansas, Fayetteville.
California. California State Mining Bureau, San Francisco.
Colorado. Colorado State Geological Survey, Boulder.
Connecticut. State Geological and Natural History Survey of Connecticut, Wesleyan University, Middletown.
Florida. Geological Survey of Florida, Tallahasse.
Georgia. Geological Survey of Georgia, Atlanta.
Illinois. Geological Survey of Illinois, Urbana.
Indiana. Department of Geology and Natural Resources, Indianapolis.
Iowa. Iowa Geological Survey, Iowa City.
Kansas. State Geological Survey of Kansas, Lawrence
Kentucky. Kentucky Geological Survey, Lexington.
Louisiana. Louisiana State Geological Survey, State University, Bâton Rouge.
Maine. State of Maine Geological Survey Commission, Bangor.
Massachusetts. Massachusetts State Geological Survey, Amherst.
Michigan. Geological Survey of Michigan, Board of Education, Lansing.
Minnesota. Geological Survey of Minnesota, Minneap .
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Missouri. Bureau of Geology, Rolla.
Nebraska. Nebraska Geological Survey, Lincoln.
New Hampshire. New Hampsh Geographical Survey, Concord.
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North Carolina. North Carolina Geological and Economic Survey, Chapel Hill.
North Dakota. North Dakota Geological Survey, State University, Grand Forks.
Ohio. Geological Survey of Ohio, Columbus
Oklahoma. Oklahoma Geological Survey, Norman.
Pennsylvania. Topographic and Geological Survey Commission, Beaver.
Rhode Island. Natural History Survey of Rhode Island, Providence.

South Carolina.	South Carolina Geological Survey, Charleston.
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West Virginia.	West Virginia Geological Survey, Morgantown.
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Ireland.	Geological Survey of Ireland, 14 Hume Street, Dublin,

INDE.

India.	Geological Survey of India, Indian Museum, Calcutta.
Mysore.	Mysore Geological Department, Bangalore

INDO-CHINE.

Service géologique de l'Indo-Chine, Inspection générale des Travaux Publics, Hanoi, Tonkin.

ITALIE.

Reale Ufficio Geologico d'Italia, Via Santa Susanna 13, Roma.

JAPON.

Japan.	Chishitsu Chosasho (Imperial Geological Survey of Japan,) Kobikichō, Kyōhashiku, Tōkyō.
Corée (Korea).	Komuka, No-Sho-Ko-Bu. (Mining Bureau, Department of Agriculture, Commerce and Industry) Seoul.
Formosa.	Chishitsu-Ka, Shokusan-Kyoku, (Geological Division, Industrial Bureau of the Government of Formosa), Taihoku.

JAVA.

Batavia.	Hoofdbureau van het Mijnwezen, Batavia.

MADAGASCAR.

Services des Mines de Madagascar, Antananarivo.

MEXIQUE.

Instituto Geologico Nacional, 6 a del Ciprès 176, Mexico, D F.

NORVÈGE

Norges Geologiske Undersøkelse, Kronprinsensgade 4, Kristiania.

NOUVELLE CALÉDONIE.

Corps des Mines du Gouvernement, Nouméa.

NOUVELLE-ZÉLANDE.

Geological Survey of New Zealand, Wellington.

PAYS-BAS.

Commissie voor het Geologisch Onderzoek, Akademie van [illegible]ten-schappen, Amsterdam.

Rijksopsporing van Delfstoffen, 's-Gravenhage.

PÉROU.

Comisión Geologica de Peru Cuerpo de Ingenieros de Minas del Peru, Lima.

LES PHILIPPINES.

Division of Mines, Bureau of Science, Manila.

PORTUGAL.

Commissão do Serviço Geologico, Rua do Arco a Jesus 113, Lisboa.

RHODESIA.

Geological Survey of Southern Rhodesia, P.O. Box 168, Bulaw[illegible]

Geological Survey of the British South Africa Company, Bulaw[illegible]

ROUMANIE.

Institutul Geologic al României, Ministerul Industriei si Comertuli, Bucarest.

EMPIRE RUSSE.

RUSSIE. Comité géologique, Wassili Ostrow, 4ème Ligne No. 15, St. Pétersbourg.

RUSSIE. Section géologique du Cabinet de sa Majesté, Musée Geologique de l'Université, St. Pétersbourg.

FINLANDE. Geologiska Kommissionen i Finland, Boulevardgatan 29, Helsingfors.

SERBIE.

Société géologique de Serbie, Université, Belgrade.

SIAM.

Royal Department of Mines and Geology, Bangkok.

SOUDAN.

Voir Égypte.

SUÈDE.

Sveriges Geologiska Undersökning, Mäster Samuelsgatan 44 Stockholm, 3.

SUISSE.

Schweizerische Geotechnische Kommission, Polytechnikum, Zürich.

TERRE-NEUVE.

Geological Survey of Newfoundland, St. John's.

UNION SUD-AFRICAINE.

UNION OF SOUTH AFRICA. Department of Mines, Union of South Africa, Pretoria.

CAPE OF GOOD HOPE.	Geological Survey of the Cape of Good Hope, Department of Agriculture, Cape Town.
TRANSVAAL.	Geological Survey of the Transvaal, Pretoria.

URUGUAY.

Instituto de Geologia u Perforaciones, Montevideo.

SOCIÉTÉS MINIÈRES.

ALLEMAGNE.

AACHEN.	Verein für die berg- und hüttenmännischen Interessen im Aachener Bezirk.
BLUMRODA.	Verein für bergbauliche Interessen der Braunkohlenwerke des Berginspektionsbezirks, Leipzig.
BROMBERG.	Verein für Förderung des Braunkoblenbergbaues in den östlichen Provinzen.
CLAUSTHAL.	Berg- und hüttenmännischer Verein "Maja."
DORTMUND.	Verein für die bergbaulichen Interessen im Oberbergamtsbezirk Dortmund.
DIEDENHOFEN.	Verein für die bergbaulichen Interessen Lothringens.
ESSEN (RUHR)	Verein für die bergbaulichen Interessen im Oberbergamtsbezirk Essen (Ruhr).
GRASLEBEN	Vereinigung der Bergwerksbesitzer im Herzogtum Braunschweig, Grasleben, Kr. Helmstedt.
HALLE A.S.	Deutscher Braunkohlen-Industrie-Verein.
HALLE A.S.	Hallescher Bergwerkverein E.V.
HALLE A.S.	Weissenfels-Teitzer Bergwerkverein.
HANNOVER.	Verein für die gemeinschaftlichen Interessen des Hannoverschen Kalibergbaues.
HELMSTEDT.	Magdeburger Braunkohlen-Bergbauverein.
KASSEL.	Bergbaulicher Verein, zu Kassel.
KATTOWITZ.	Oberschlesischer berg- und hüttenmännischer Verein.
KÖLN.	Verein für die Interessen der rheinischen Braunkohlenindustrie.
MAGDEBURG.	Verein der deutschen Kaliinteressen.
METZ.	Verein deutscher Eisenhüttenleute.
METZ.	Verein für die bergbaulichen Interessen Elsass-Lothringens.
MÜNCHEN.	Verein bayerischer Bergbauinteressenten.
OSCHERSLEBEN A. D. BODE.	Magdeburger Braunkohlen Bergbau-Verein.
SENFTENBERG, N. L.	Verein für die bergbaulichen Interessen Niederschlesiens.
SIEGEN.	Berg- und hüttenmännischer Verein.
STASSFURT.	Verband für Wissenschaftlichen Erforschung der deutschen Kalisalzlagerstätten.
WALDENBURG.	Verein für die bergbaulichen Interessen Niederschlesiens.
WETZLER.	Berg- und hüttenmannischer Verein für die Lahn-, Dill- und benachbarten Reviere.
LITTAN i S.	Verein für Bergbau-interessen der Braunkohlenwerke im Berg-inspektions-Bezirk Dresden.
ZWICKAU i S.	Bergbaulicher Verein für Zwickau und Lugau-Oelsnitz.

AUSTRALIE.

BALLARAT.	The Amalgamated Mining Managers Association of Australasia, 25 Mining Exchange, Ballarat.
CHARTERS TOWERS. (QUEENSLAND).	North Queensland Mining and Mill Managers Association, Bow Street.
MELBOURNE.	Australasian Institute of Mining Engineers, 57-59 Swanston Street.

MELBOURNE. The Chamber of Mines of Victoria.
KALGOORLIE (WESTERN AUSTRALIA). The Chamber of Mines of Western Australia.

ÖSTERREICH. AUTRICHE-HONGRIE.

FALKENAU. Berg- und hüttenmännischer Verein in Falkenau für die Bergreviere Falkenau, Elbogen und Karlsbad.
KLAGENFURT. Berg- und hüttenmännischer Verein für Steiermark und Kärnten.
MÄHRISCH-OSTRAU. Berg- und hüttenmännischer Verein.
MÄHRISCH-OSTRAU Betriebsleiterverband für den Bergbau in Mähren und Schlesien.
TEPLITZ. Verband der Bergbaubetriebsleiter für die Revierbergamtsbezirke Teplitz, Brüx und Komotau.
TEPLITZ. Verein für die bergbaulichen Interessen im nordwestlichen Böhmen.
TEPLITZ-SCHÖNAU. Zentralverband der Bergbau-Betriebsleiter.
WIEN. Fachgruppe der Berg- und Hütteningenieure des Oesterreichischen Ingenieur- und Architektenvereines, Eschenbachgasse 9, Wien III.
WIEN. Internationaler Verein der Bohrtechniker, Scheidlstrasse 26, Wien XVIII/2.

UNGARN.

BUDAPEST. Orszagos Magyar Banyaszati- es Kohaszati egyesulet (Société des Ingénieurs des Mines), Veres Palne út. 3.
BUDAPEST. Magyar Banya- es Kohovallalatok egyesulet (Institution des Inspecteurs des Mines), Sas út. I.
BUDAPEST. Société hongroise minière et métallurgique.

BELGIQUE.

ANVERS. Association des ingénieurs de l'École des Mines de Liége.
FRAMERIES. National Federation of Miners of Belgium. Care of "Ouvrier Mineur" ("De Mijnwerker").
LIÈGE. Union des Charbonnages, Mines et Usines métallurgiques de la Province de Liége.
LIÈGE Association des Ingenieurs sortis de l'École de Liége, 16 Quai de l'Université Liége
LOUVAIN. Association des Ingenieurs sortis de l'École des Mines de Louvain, 18 Rue Joyeuses Entrées.
MONS. Association des Ingénieurs des Mines sortis de l'École des Mines du Hainaut.

CANADA.

HALIFAX. The Mining Society of Nova Scotia, 23 Hollis Street.
MONTREAL. Canadian Mining Institute, Ritz-Carlton Hotel.

CHILE.

SANTIAGO. La Sociedad Nacional de Mineria de Chile.

COLOMBIE.

BOGOTA. Sociedad Colombiana de Ingenieros.

EMPIRE RUSSE.

ST.-PETERSBOURG. Société des Ingénieurs des Mines, Gorochowaja No. 12.

ÉTATS-UNIS D'AMÉRIQUE.

CHARLESTON, VA. West Virginia Mining Association.
COLUMBUS, OHIO. Mine Inspectors' Institute of the United States.
CRIPPLE CREEK, COL. Cripple Creek Mining and Metallurgical Society.
DENVER, COL. American Mining Congress, 725 Majestic Building.
DENVER, COL. Colorado Scientific Society, 418 Boston Building.
ISHPEMING, MICH. Lake Superior Mining Institute.

New York.	American Institute of Mining Engineers, 29 West 39th St.
New York.	Bituminous Coal Trade Association, 1 Broadway.
New York.	Mining and Metallurgical Society of America, 505 Pearl St.
Pittsburg, Pa.	Coal Mining Institute, 108 Smithfield Street.
Pittsburg, Pa.	Mine Inspectors' Institute of the U.S.A. Care of J. W. Paul, 40th and Butler Streets.
San Francisco, Cal.	Seismological Society of America.

FRANCE.

Alais.	Société des anciens élèves de l'École des Maîtres Mineurs d'Alais.
Douai.	Société des anciens élèves de l'École des Maîtres Mineurs de Douai.
Nancy.	Comité des Forges et des Mines de Fer de Meurthe-et-Moselle, 40 rue Gambetta.
Paris.	Chambre syndicale française des Mines métalliques, 55 rue de Châteaudun.
Paris.	Association amicale des Ingénieurs de l'École centrale des Mines.
Paris.	Société des anciens élèves de l'École des Mines de Paris, 39 rue Godot de Mauroy.
	Société de l'industrie minérale.
	Comité central des Houillères de France.
St. Étienne, Loire.	Société amicale des anciens élèves de l'École nationale des Mines de St. Étienne, 19 rue du Grand Moulin.
St. Étienne, Loire.	Société de l'industrie minérale.

ILES BRITANNIQUES.

ANGLETERRE.	
Barnsley.	Midland Institute of Mining, Civil and Mechanical Engineers, Secretary, G. Blake Walker, Tankersley.
Birmingham.	South Staffordshire and Warwickshire Institute of Mining Engineers, 3 Newhall Street.
Derby.	Midland Counties Institution of Engineers, Secretary, G. Alfred Lewis, Midland Road.
Derby.	Association of Mining and Electrical Engineers, Bank Chambers, London Road.
London, S.W.	Institution of Mining Engineers, 39 Victoria Street.
London, E.C.	Institution of Mining and Metallurgy, Salisbury House, London Wall.
London, S.W.	Iron and Steel Institute, 28 Victoria St.
London, W.C.	National Association of Colliery Managers, 165 Strand.
Manchester.	Manchester Geological and Mining Society, 5 John Dalton Street.
Newcastle-on-Tyne.	North of England Institute of Mining and Mechanical Engineers, Neville Hall.
Sheffield.	Midland Intitute of Mining, Civil and Mechanical Engineers, University College.
Stoke-on-Trent.	North Staffordshire Institute of Mining and Mechanical Engineers.
Wigan.	Mining Association of Great Britain.
ÉCOSSE.	
Glasgow.	Mining Institute of Scotland, 39 Elmbank Crescent.
GALLES.	
Cardiff.	South Wales Institute of Engineers, Park Place.

INDE.

Calcutta.	Mining and Geological Institute of India, 2 Banksball Street.

ITALIE.

Sardinia.	Association minérale sarde, Iglesias.

SICILIA.

Caltanisetta.	Società dei Liciati della Regia, Scuola Mineraria di Caltanisetta.

MADAGASCAR.

TANANARIVE. Chambre des mines de Madagascar.

MEXIQUE.

MEXICO. Instituto Mexicano de Minas y Metalurgia, Ap. Postal No. 1753.

NORVÈGE.

KRISTIANIA. Norsk Bergindustri Forening.

NOUVELLE-ZÉLANDE.

WELLINGTON. Mining Institute of New-Zealand.

NIGERIA.

JOS DISTRICT. Association of Mining Engineers and Chamber of Mines of Northern Nigeria. Care of Nigeria Company, Jos District, Northern Nigeria, via Keffi.

PAYS-BAS.

DELFT. Mijnbouwkundige Vereeniging te Delft.

PÉROU.

LIMA. Cuerpo de Ingenieros de Minas del Peru.

LIMA. Sociedad Nacional de Mineria, Calle de la Caridad 606, Lima, Apartado 325.

RHODESIA.

BULAWAYO. Rhodesian Chamber of Mines.

SERBIE.

BELGRADE. Société minière de Serbie, Département des Mines, Ministère de l'Agriculture, Belgrade.

UNION SUD-AFRICAINE.

TRANSVAAL.

JOHANNESBURG. Chemical, Metallurgical and Mining Society of South Africa, Post Office Box 1183.

JOHANNESBURG. Transvaal Chamber of Mines.

JOHANNESBURG. Association of Mine Managers of the Transvaal (Incorporated), Post Office Box 4609.

SUÈDE.

LANGSBANSHYTTAN. Wermländska Bergsmannaföreningen.

OREBRO. Bergshandteringen Vänner.

OREBRO. Svenska Teknologföreningen, Avdelning for Kemi och Bergsvetenskap.

STOCKHOLM. Jernköntoret.

EXCURSIONS.

I.—Excursions avant la session.

II.—Excursions pendant la session.

III.—Excursions après la session.

Excursion A 1.

QUEBEC AND MARITIME PROVINCES.

JULY 13TH—AUGUST 1ST.

Leader: G. A. YOUNG.
Associate leaders: J. M. CLARKE, E. R. FARIBAULT.
Secretary: R. HARVIE.
Assistant secretary: A. MAILHIOT.
Members: F. D. ADAMS, Canada; Mrs. ADAMS, Canada; K. ANDRÉE,
Germany; H. ARLT, Germany; L. W. BAILEY, Canada; M. B.
BAKER, Canada; J. A. BANCROFT, Canada; A. E. BARLOW, Canada;
W. L. BARROWS, U.S.A.; W. A. BELL, Canada; K. BODEN, Ger-
many; H. L. BOWMANN, England; R. W. BROCK, Canada; L. D.
BURLING, Canada; T. CANTLEY, Canada; H. M. CADELL, Scotland;
J. CAILLEHOTTE, France; R. G. CARRUTHERS, Scotland; R. E.
CHAMBERS, Canada; L. H. COLE, Canada; H. P. CUSHING, U.S.A.;
H. ECKFELDT, U.S.A.; S. M. GARDNER, Scotland; M. I. GOLDMAN,
U.S.A.; J. W. GOLDTHWAIT, Canada; C. R. GUIMONT, Canada;
G. GÜRICH, Germany; C. A. HANIEL, Germany; C. HARTNAGEL,
U.S.A.; E. HAYCOCK, Canada; A. O. HAYES, U.S.A.; O. HAYWARD,
Canada; J. A. L. HENDERSON, England; B. HOBSON, England;
E. A. HOLBROOK, Canada; O. HOLTEDAHL, Norway; R. E. HORE,
Canada; J. P. HOWLEY, Canada; J. McG. HURLL, Scotland;
M. HURLL, Scotland; J. E. HYDE, Canada; J. T. JEHU, Scotland;
W. F. JENNISON, Canada; C. KIDO, Japan; E. M. KINDLE, Canada;
H. B. KÜMMEL, U.S.A.; L. M. LAMBE, Canada; A. C. LAWSON,
U.S.A.; W. S. LECKY, Canada; P. LORY, France; S. G. MARTIUS,
Germany; G. F. MATTHEW, Canada; H. MCPHERSON, Canada;
L. MICHALON, France; H. E. MITSCHERLICH, Germany; T. C.
NICHOLAS, England; C. M. PART, England; W. PAULCKE, Germany;
H. PIERS, Canada; S. POWERS, U.S.A.; P. PRUVOST, France;
P. D. QUENSEL, Sweden; Miss A. RATHGEN, Germany; P. E.
RAYMOND, U.S.A.; A. J. RIEDEL, Germany; H. SAINT-CLIVIER,
France; E. O. SANDERS, Canada; C. SCHUCHERT, U.S.A.; F. H.
SEXTON, Canada; F. S. STEVENS, Canada; A. STRAHAN, England;
E. STOLLEY, Germany; P. M. TERMIER, France; Mlle. M. TER-
MIER, France; N. TILLMAN, Germany; I. P. TOLMAČEV, Russia;
W. H. TWENHOFEL, U.S.A.; E. O. ULRICH, U.S.A.; F. VON GROTE,
Germany; O. A. WELTER, Germany; B. WEIGAND, Germany;
E. WIGGLESWORTH, U.S.A.; J. B. WOODWORTH, U.S.A.; J. M.
WORDIE, England; W. J. WRIGHT, Canada; P. ZOUDE, Belgium;
R. ZUBER, Austria.

(See Guide Book No. I. Parts I and II.)

Excursion A 2.

HALIBURTON–BANCROFT, ONTARIO.

JULY 24TH–31ST.

Leaders: F. D. ADAMS and A. E. BARLOW.

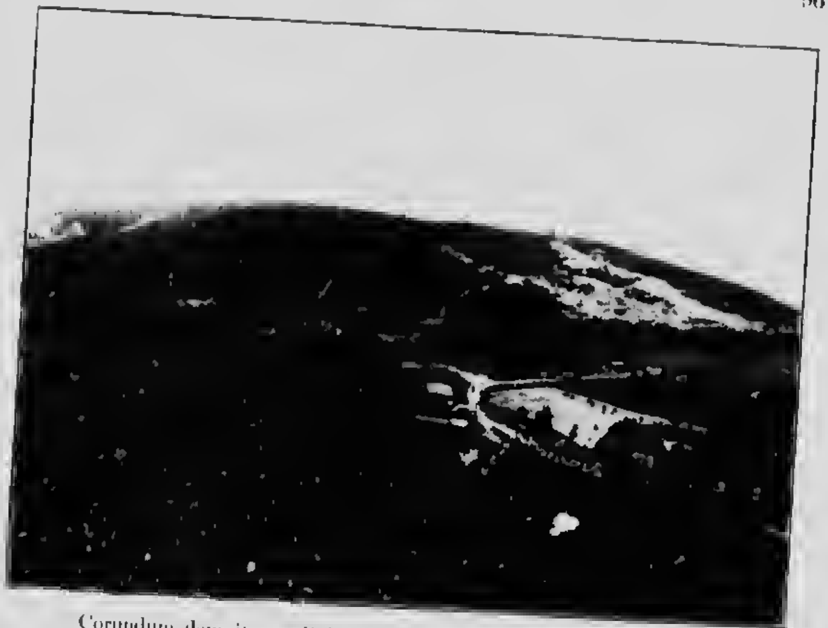
Secretary: G. C. MACKENZIE.

Members: W. ARSCHINOW, Russia; H. BÄCKSTRÖM, Sweden; Miss FLORENCE BASCOM, U.S.A.; C. P. BERKEY, U.S.A.; A. BERGEAT, Germany; MAX BELOWSKY, Germany; C. CARTWRIGHT, Canada; WHITMAN CROSS, U.S.A.; R. A. DALY, U.S.A.; T. C. DENIS, Canada; A. L. DAY, U.S.A.; J. DRUGMAN, Belgium; C. N. FENNER, U.S.A.; L. L. FERMOR, India; H. FRÉCHETTE, Canada; PER GEIJER, Sweden; A. C. GILL, U.S.A.; A. HARKER, England; BERNARD HOBSON, England; S. KOZU, Japan; ALFRED LACROIX, France; Madame LACROIX, France; C. K. LEITH, U.S.A.; L. MICHALON, France; R. B. MURRAY, England; C. PALACHE, U.S.A.; L. M. PRINDLE, U.S.A.; P. D. QUENSEL, Sweden; J. J. SEDERHOLM, Finland; C. VISCONT, Russia; J. E. WOLFF, U.S.A.; F. E. WRIGHT, U.S.A.

Excursion A 2 was arranged to enable members of the Congress to see a typical Pre-Cambrian area in eastern Canada. The Pre-Cambrian of the part of central Ontario covered by the excursion probably presents a greater variety of rock types than has been described from any similar area of ancient crystalline rocks in North America. It shows in a striking manner the progressive metamorphism of the Grenville-Hastings series resulting from Laurentian batholithic intrusions. It also contains a very extensive and remarkable development of nepheline rocks, among which are many rare and some unique types.

On July 24th the special train carrying the excursionists left Montreal by the Grand Trunk railway and at Trenton, 230 miles from Montreal, was switched to the Central Ontario branch of the Canadian Northern railway. At Millbridge station, 50 miles farther, the party left the railway and drove northward along the Hastings road for about 15 miles, for the purpose of seeing the section of Pre-Cambrian rocks which the road crosses nearly at right angles to their strike.

The rocks exposed in the section are chiefly limestones, paragneisses, amphibolites and gabbro-diorite. The progressive metamorphism of the bluish or bluish-grey limestones into whiter and more crystalline varieties is very well exemplified by the exposures examined. Between lots 40 and 56, Hastings road, the sedimentary series is interrupted by an intrusion of



Corundum deposits on Robillard Mountain at Craigmont, Ontario.
Photo by A. E. BARLOW

Excursion A 2 at Stewart quarry, Ontario Marble Quarries near Bronson, Ontario.
Photo by A. E. BARLOW

gabbro-diorite (Hole-in-the-wall diorite) which differentiates in certain places, especially along the border, as at the Orton iron mine, into a titaniferous magnetite. Through the kindness of Mr. J. W. EVANS of the Tivani Electric Steel Company of Belleville, the excursionists were provided with lunch at the Orton mine.

At St. Ola station the party again entrained and proceeded to Ormsby Junction, in the vicinity of which exposures of very typical, rusty weathering paragneisses were examined. With a short stop south of L'Amable station to see and collect some of the characteristic "feather" amphibolite, the party reached Bronson station at 6.30 p.m. on Friday, July 25th.

The morning of Saturday, July 26th, was spent in an examination of the quarries of the Ontario Marble Quarries, Limited, to the west of Bronson station. These singularly beautiful, coloured marbles and breccias are well exposed in the Stewart and Baker quarries, while a white variety, often with a veined or streaked appearance, is being extensively worked at the White quarry. The afternoon was spent in a critical study of the junction between the nepheline rocks and the Grenville crystalline limestone, exposed in the railway cutting at the village of Bancroft. Fragments of the limestone have been incorporated in the nepheline syenites and the calcareous rocks have been intensely metamorphosed by the intrusion of the batholith of alkaline syenites. The Princess (sodalite) quarries about three miles east of Bancroft were examined, also the nepheline and alkaline syenite exposure north of Bancroft and the Laurentian batholith at Eagle's Nest.

A special train provided by the Canadian Northern railway, consisting of a light first-class passenger car and the private car of Mr. COLLINS, the manager of the Central Ontario railway, conveyed the party over the line of the Irondale Bancroft and Ottawa railway. Leaving Bancroft at 8 a.m. on Sunday, July 27th, the first geological section examined was that exposed near Baptiste Lake station, where the line of junction between the Grenville series and the granite batholith was examined. The cuttings on the railway show good sections of the crystalline limestones and interstratified, rusty-weathering paragneisses. The beds are very much contorted and in places are intruded by apophyses emanating from the granitic batholith; autoclastic structure is developed in them in many places by the dislocation of the gneissic bands and the flowing of the limestone.

The closely related contact phenomena occasioned by the intrusion of the Laurentian granite-gneiss batholith through the crystalline limestones in the vicinity of Maxwell's Crossing (42.5 m. from Bancroft) were also made the subject of special scrutiny. The development of amphibolite as a direct product of the metamorphism of the limestone by the granite-gneiss batholith was thoroughly convincing and interesting.

In the afternoon, to the southeast of Gooderham, exposures of nepheline-syenite pegmatite, nepheline syenite with hastingsite, and gabbro were seen and studied.

On Monday, July 28th, the special train carried the visiting geologists to Mumford station where certain varieties of nepheline syenite, especially those rich in hornblende, were examined and collections were made of typical material. In the afternoon the excursionists walked from the crossing of the road immediately west of Tony Hill station to Hadley's Crossing, a distance of about six miles. On the way, exposures of the several varieties of the nepheline and alkaline syenites already described were studied.

The special train remained on the siding at Bancroft and was used as headquarters until the morning of Tuesday, July 29th, when the whole party drove across to Bronson Landing on the York river. Here they embarked in two of the rough boats known to lumbermen as pointers, one of which, driven by a gasoline motor, towed the other. Landings were made in Dungannon and Monteagle to study the occurrence of corundum in dungannonite (andesine-anorthosite). Combermere was reached in the evening, after a delightful trip down the York river.

Wednesday, July 30th, was occupied in a detailed examination of the nepheline and alkaline syenite and anorthosites with corrundum on Robillard mountain at Craigmont, the members returning to Combermere for the night.

On Thursday, July 31st, the excursionists sailed by steamer from Combermere up the Madawaska river and Kamaniskeg lake to Barry's Bay, where they entrained at 3 p.m., reaching Ottawa by the Grand Trunk railway about 6.30 p.m.

A. E. BARLOW.

Excursion A 3.

SUDBURY—COBALT—PORCUPINE.

JULY 23RD—AUGUST 2ND.

Leader: W. G. MILLER.
Guides (1) Sudbury: A. P. COLEMAN, T. L. WALKER.
(2) Cobalt: C. W. KNIGHT, A. A. COLE.
(3) Porcupine: A. G. BURROWS, P. E. HOPKINS.
Secretary: W. R. ROGERS.
Members: H. BAIN, U.S.A.; J. BARRELL, U.S.A.; S. CERULLI-IRELLI, Italy; A. G. CHARLETON, England; Mrs. CHARLETON, England; G. A. J. COLE, Ireland; W. H. COLLINS, Canada; J. A. DRESSER, Canada; H. ECKFELDT, U.S.A.; Mrs. ECKFELDT, U.S.A.; Miss ANNIE EUBANK, Canada; F. X. FOREST, Canada; G. W. GRABHAM, Egypt; R. E. HORE, Canada; F. A. JORDAN, Canada; J. F. KEMP, U.S.A.; A. E. KITSON, England; A. C. LANE, U.S.A.; H. LANTENOIS, Indo-China; E. LINDEMAN, Canada; E. MATTIROLO, Italy; C. McDERMID, England; B. McNEILL, England; Mrs. McNEILL, England; G. MERCIAI, Italy; L. J. MORIN, Canada; A. NOISEUX, Canada; P. P. PIATNIZKY, Russia; O. F. PFORDTE, U.S.A.; F. L. RANSOME, U.S.A.; L. REINECKE, Canada; H. SCHULZE, Germany; F. SEARLS, U.S.A.; W. E. SIMPSON, Mexico; H. S. A. SJÖGREN, Sweden; J. DE. SZÁDECZKY, Hungary; J. B. TYRRELL, Canada; Mrs. TYRRELL, Canada; H. B. WALLIS, England; A. W. G. WILSON, Canada; M. E. WILSON, Canada; A. G. B. WILBRAHAM, England.

Excursion A 3 left Toronto by special train on the Canadian Pacific railway on the evening of Wednesday, July 23rd, for Sudbury, where three days were spent in a study of the Pre-Cambrian geology and in visiting some of the more important nickel-copper mines and plants. A visit was also made to the iron mine and plant at Moose mountain, where luncheon was kindly provided by the mining company. On Friday evening the President and Members of the Sudbury Board of Trade gave a banquet in honour of the excursionists. A description of the Sudbury area is given in Guide Book No. 7 together with references to the more detailed reports relating to the district.

On Sunday, July 27th, the special train left Sudbury for Cobalt via North Bay, arriving there in the evening. En route the excursionists had an opportunity of seeing something of the geology of this part of northern Ontario, a description of which is given in the guide book. Monday and

Tuesday, July 28th and 29th, were spent in a study of the geology of Cobalt and visits to mines and works. On Monday evening the members of the Cobalt Branch of the Canadian Mining Institute tendered a reception to the excursionists. A steamboat excursion was made on Tuesday afternoon from Haileybury down to the narrows in Lake Timiskaming and back. On Tuesday evening the special train proceeded to Porcupine, where Wednesday was spent in visits to the Dome, Hollinger, McEnaney and other gold mines. Meantime, on the afternoon of Tuesday, July 29th, a few members of the party had proceeded to the new gold camp at Kirkland lake; they joined the main party en route to Porcupine on Tuesday night.

On Wednesday night, July 30th, the train proceeded from Porcupine to Timagami, 25 miles south of Cobalt, where a day was spent. An excursion was made by steamboat from Timagami station to Timagami Inn on the island of the same name. On the return to the station a visit was made to the Keewatin iron formation, or jaspilite, and other interesting exposures of rock near Timagami. On the afternoon of Thursday, July 31st, the special train proceeded from Timagami to North Bay, a short stop being made at Doherty station to examine certain Pre-Cambrian fragmental and igneous rocks; from North Bay the train proceeded during the night to Ottawa. Friday, August 1st, was spent in Ottawa, under the direction of the Ottawa local committee, with members of other excursion parties who had also gathered in the city. Friday evening the train proceeded to Montreal, thus completing the excursion.

W. G. Miller.

Excursion A 4.

NIAGARA—IROQUOIS BEACH.

AUGUST 4TH—6TH.

Leader: A. P. COLEMAN.
Associate leader: F. B. TAYLOR.
Secretary: W. R. ROGERS.
Members: S. CERULLI-IRELLI, Italy; A. C. CHARLETON, England; Mrs. CHARLETON, England; A. E. DAY, Syria; H. ECKFELDT, U.S.A.; Mrs. ECKFELDT, U.S.A.; A. HAGUE, U.S.A.; P. E. HOPKINS, Canada; E. MATTIROLO, Italy; C. McDERMID, England; D. McINTOSH, Canada; B. McNEILL, England; Mrs. McNEILL, England; G. MERCIAI, Italy; G. A. MOLENGRAAFF, Netherlands; J. W. SPENCER, U.S.A.; P. STEPANOV, Russia; A. STRAHAN, England; Mrs. F. B. TAYLOR, U.S.A.; I. P. TOLMAČEV, Russia.

As August 4th was the annual civic holiday at Toronto and the steamers for Niagara were greatly crowded, the excursion left by the 9 o'clock steamer instead of the earlier one. The officials of the steamboat company gave much assistance in getting the party comfortably on board in spite of the crowds; and the programme for the day was carried out completely, though at somewhat later hours than had been announced.

During the first day the usual points of view of the falls on both sides of the river were visited, a short voyage was made on the *Maid of the Mist*, and by the courtesy of the Electric Development Company, which supplies much of the power used in Toronto, their intake was examined and the party were taken down to the bottom of the penstocks where the turbines were at work.

In the evening after dinner at the Clifton hotel there was an informal gathering at which Mr. F. B. TAYLOR and Dr. J. W. SPENCER explained their views as to the complex history of the falls and gorge. As these were quite divergent in regard to many points there was a lively discussion which proved very interesting to the members of the excursion.

August 5th was devoted mainly to a study of the gorge and rapids below the falls, making use of the gorge railway. Sir HENRY PELLATT, president of the Electric Development Company, was good enough to provide the private car *Ondiara* for the use of the party. Stops were made at various points and there was a longer stay at Niagara Glen, where the party followed the beautiful walks through the woods and along the rapids. An excellent lunch was provided by the Electric Development Company under the trees beside the rapids. In the afternoon the river was crossed at Queenston and a walk was taken to the extraordinary cross-bedded gravels at Lewiston, which were studied with much interest. There was a good deal of discussion as to whether they were formed by powerful currents when the falls first poured over Queenston Heights, or by some unusual wave action during the time of Lake Iroquois, and no very certain conclusion was reached.

Returning to the falls by the gorge route on the American side, the night was spent at the Clifton Hotel.

On August 6th, the Grand Trunk railway was taken to Hamilton, the excursionists thus passing down from the Niagara escarpment to the Iroquois terrace through the famous fruit-growing region. The Hamilton Local Committee met the party with motor cars, taking the members through the city to the remarkable gravel bar of Lake Iroquois at Burlington Heights. The cars then ran out the Guelph road to the brow of the escarpment, from which there is a broad view over the Iroquois beach and the west end of Lake Ontario. On the return, before reaching Watertown, an unmapped drumlin was discovered near the road.

After a reception held by his Worship Mayor ALLAN and the local Ladies' Committee at the Royal Hotel, a luncheon was tendered to the party by the courtesy [illegible] the City of Hamilton and the Canadian Club.

During the afternoon the Silurian section in the escarpment to the south of the city was examined and a short visit was made to the museum of the Hami[illegible] ssociation to see a collection of local fossils. The party returned to To[illegible] by rail in time for dinner.

A. P. COLEMAN.

Excursion A 5.

GISEMENTS D'AMIANTE DE LA PROVINCE DE QUÉBEC.

2–7 AOÛT.

Conducteurs conjoints: T. C. DENIS et J. A. DRESSER.

Secrétaire: H. FRÉCHETTE.

Guides: R. HARVIE, A. MAILHIOT.

Membres: HANS ARLT, Allemagne; H. F. BAIN, États-Unis; C. P. BERKEY, États-Unis; S. W. BEYER, États-Unis; K. BODEN, Allemagne; O. B. BÖGGILD, Danemark; H. BORGSTRÖM, Finlande; P. FABREGA, Espagne; L. L. FERMOR, Inde; Mrs. FERMOR, Inde; S. McL. GARDNER, Écosse; F. VON GROTE, Allemagne; G. GÜRICH, Allemagne; R. E. HORE, Canada; J. P. HOWLEY, Terre-Neuve; M. HURLL, Écosse; C. KIDO, Mandchourie; P. J. KRUSCH, Allemagne; A. C. LAWSON, États-Unis; S. G. MARTIUS, Allemagne; R. B. MURRAY, Angleterre; C. PALACHE, États-Unis; F. SEARLS, États-Unis; B. WEIGAND, Allemagne; O. A. WELTER, Allemagne; E. T. WHERRY, États-Unis; E. WIGGLESWORTH, États-Unis; A. G. B. WILBRAHAM, Angleterre; B. WILLIS, États-Unis; J. E. WOLFF, États-Unis; P. L. G. ZOUDE, Belgique.

Le but de cette excursion était de visiter, sur le terrain, les affleurements et les relations des roches diverses constituant la zone serpentineuse de la province de Québec, au sein de laquelle se trouvent les gisements d'amiante qui donnent lieu à une exploitation intensive, et les intéressants dépôts de chrome. Le conducteur en œuvre de cette excursion était M. J. A. DRESSER.

Un train spécial, de cinq wagons, partait de Montréal, (gare Bonaventure) à 10.30, le samedi soir, 2 août, et arrivait à Black Lake, une distance de 165 milles, de bonne heure dimanche matin, où commençaient nos excursions sur le terrain. Toute la journée de dimanche fut passée à observer la géologie de Black Lake et des environs. Lundi matin, 4 août, quinze voitures, hétérogènes, du phaéton au char-à-bancs, transportaient les excursionistes à quatorze milles de Black Lake, aux gisements de chrome connus sous le nom de "Montreal Pit," près du Petit Lac St.-François. Mardi matin, le train nous menait à East Broughton, à 20 milles au nord de Black Lake pour examiner les gisements d'amiante à cet endroit, lesquels diffèrent sensiblement de ceux de Thetford et de Black Lake. Mardi midi, retournant sur nos pas, jusqu'à Thetford Mines, qui est distant de quatre milles de Black Lake, nous y visitâmes les mines d'amiante et les ateliers de préparation. Mercredi matin, 6 août, nous partions de Thetford, en voyage de retour. Arrêt d'une heure et demie à Coleraine pour voir des affleurements des brèches de la zone du contact des intrusions batholithiques avec les roches sédimentaires. Arrivée à Sherbrooke à deux heures, où des automobiles mises à notre disposition par un comité des citoyens de Sherbrooke nous permettaient de visiter la ville et l'un des principaux établissements industriels. Départ de Sherbrooke à quatre heures pour arriver à Montréal à huit heures, et à Toronto le lendemain jeudi, 7 août, à sept heures du matin.

Brièvement, les roches que nous examinâmes au cours de l'excursion A 5 font partie d'une bande ou zone de roches intrusives basiques, orientée N.E.-S.W., qui est, plus ou moins, continue entre la frontière du Vermont et la rivière Chaudière, (200 kilomètres), sur une largeur maximum de 10 kilomètres, et qui est constituée par des péridotites et serpentines, pyroxénites, gabbros, diabases, porphyrites, granites, amphiboliques et aplites, tous ces membres de la série étant considérés comme des produits de la différenciation d'un même magma. De ces roches, la péridotite a été altérée en serpentine, et c'est au sein de cette dernière que se sont développées les veines d'amiante de Thetford et de Black Lake, dont l'exploitation fournit actuellement plus de 80 pour cent de la production mondiale d'amiante.

Les gisements de fer chromé du Petit Lac St.-François se trouvent aussi dans une péridotite en partie serpentinisée, près d'un massif de diabase. Ce gisement est intéressant pour les minéralogistes, car, au sein des phases granitiques dont on trouve des développements même dans les roches ultrabasiques, on observe la présence de divers minéraux, tels que vésuvianite, cristaux de talc, grenats incolores, etc. Le Dr. PALACHE, armé d'un gros marteau de trois kilos, et d'une énergie qui fit l'admiration de tous, vit ses efforts récompensés par l'obtention de très beaux spécimens.

Le mode de formation de l'amiante et l'altération de l'olivine ou péridot, en serpentine, donna lieu à des discussions intéressantes. Cette altération est, en grande partie, un processus d'hydration de l'olivine, tant pour la génèse de la serpentine que celle de l'amiante. Dans certaines mines, on a actuellement atteint une profondeur de 80 mètres, et à cette distance de la surface, on n'observe aucun changement, ni dans la nature des roches des gisements, ni dans la qualité de l'amiante, ni même dans la teneur en amiante. Il semblerait donc que l'amiante doit son origine à un processus qui eut lieu en profondeur, et dans lequel les eaux et vapeurs magmatiques des roches ignées entrent en ligne de compte comme agents d'hydration, plutôt que les eaux météoriques; quoique ces dernières aient aussi pu jouer un certain rôle.

Au voyage de retour, les excursionistes s'arrêtèrent une heure et demie à Coleraine pour examiner les brèches de contact résultant de l'action du magma sur les roches envahies, et que l'on retrouve en divers endroits sur le pourtour du batholithe.

Après un arrêt de deux heures à Sherbrooke, le train arrivait à Montréal à huit heures du soir, et à Toronto jeudi matin, le 7 août, pour l'ouverture des Sessions du Congrès.

T. C. DENIS.

Excursion A 6.

THE MORIN ANORTHOSITE AREA, QUEBEC.

Leader: J. Austen Bancroft.
Guide: R. P. D. Graham.
Secretary: J. H. Valiquette.
Members: W. Archinow, Russia; H. Bäckström, Sweden; A. Bergeat, Germany; W. Cross, U.S.A.; H. P. Cushing, U.S.A.; A. L. Day, U.S.A.; R. A. Daly, U.S.A.; P. Geijer, Sweden; A. C. Gill, U.S.A.; C. Godfroy, Netherlands; G. W. Grabham, Sudan; Abbé C. R. Guimont, Canada; A. Harker, England; J. Horne, Scotland; E. Howe, U.S.A.; J. F. Kemp, U.S.A.; S. Kozu, Japan; A. Lacroix, France; Madame Lacroix, France; H. Lantenois, Indo-China; F. Loewinson-Lessing, Russia; W. Loewinson-Lessing, Russia; L. Michalon, France; L. M. Prindle, U.S.A.; Miss C. A. Raisin, England; P. Termier, France; C. Viscont, Russia; F. E. Wright, U.S.A.

Excursion A 6, which occupied one day, was arranged to afford members of the Congress an opportunity of examining one of the bodies of anorthosite which penetrate the earlier Pre-Cambrian rocks of the Canadian Shield. The intrusive visited, known as the Morin anorthosite, is situated about 30 miles north of Montreal and is easily accessible. It has an area of 990 square miles, and is roughly circular in outline, departing from that shape only on the southeastern side, where a wide apophysis projects southward. Although small in comparison with some of the other similar intrusions, it is a typical representative of them.

The excursion followed the line of the Canadian Pacific railway from Montreal to Ste. Marguerite; then, after returning to St. Jerome, where lunch was served, the excursionists spent the rest of the day in visiting outcrops near New Glasgow and Ste. Sophie along the line of the Canadian Northern railway.

The anorthosite penetrates the gneissoid Laurentian granite, which in turn intrudes the Grenville series, the latter comprising more or less metamorphosed sedimentary rocks, among which narrow bands of crystalline limestone are worthy of special mention. In a few localities, dark dykes of gabbro and diabase traversing the anorthosite represent the youngest Pre-Cambrian rocks within this area.

For the most part, the anorthosite is a massive, coarse-grained rock of a deep violet colour. Plagioclase feldspar, which wherever examined has proved to be labradorite containing a vast number of minute schillerization inclusions, forms approximately 95 per cent of the rock, while the remaining constituents are augite, hypersthene and ilmenite. Typical anorthosite of this variety was examined in the railway cutting, a mile and a quarter beyond Ste. Marguerite. A quarter of a mile east of this cutting, a band of rusty-weathering, garnetiferous anorthosite, containing a considerable amount of pale-green augite and ilmenite, marks the position of a line of movement within the mass.

Towards the periphery of the mass the rock presents an entirely different appearance; and this marginal facies was seen at New Glasgow. There, the weathered surface of the anorthosite is almost snow-white, and the rock itself is light in colour, fine-grained and foliated, presenting a remarkable contrast to the dark, massive variety previously examined. This loss of colour is usually due to the extreme granulation of the feldspar individuals produced by the pressure and movement to which the rock has been subjected. At New Glasgow, where the pressure has been exceptionally intense, the granulation has been accompanied by partial recrystallization.

A few hundred yards south of the Canadian Pacific railway station at St. Jerome, a small, irregular body of gabbro was visited, within which the rock is finer in grain and contains a greater abundance of ferro-magnesian minerals (augite, hypersthene, hornblende, biotite, garnet and iron-ore) than the typical anorthosite of the Morin area. The foliated character of the rock, and the presence of remnants of individuals of dark-coloured plagioclase, occasionally six inches in length, which have been curved, twisted and partially granulated, point clearly to the activity of crushing stresses. The marginal facies of this gabbroid intrusion is intermediate in petrographical character between the typical gabbro and the Laurentian orthoclase-gneiss which it intrudes. The opinion was expressed informally by some members of the party, that this gabbro of St. Jerome may be regarded as a differentiation product of the anorthosite magma. This is probable, but must remain a matter of opinion since the gabbro of St. Jerome is separated from the Morin anorthosite by several miles of intervening gneiss. The gabbro at St. Jerome is intersected by several narrow diabasic dykes.

Near Ste. Sophie, a short distance west of L'Achigan river, a great dyke of nearly black gabbro traverses the Morin anorthosite, and may be followed northward for nine miles. It is foliated parallel to its sides and contains numerous inclusions of the anorthosite.

No exposures showing the anorthosite in contact with the gneissoid Laurentian granite were visited, but an outcrop of the latter rock was seen near Ste. Sophie. There, the "leaf-gneiss," so called because of its extreme foliation, is fine-grained, pink in colour, and occasionally displays well developed augen of the more resistant feldspar individuals. A few narrow bands of highly altered limestones of the Grenville series were seen in direct association with the gneiss.

R. P. D. GRAHAM.

Excursion A 7.

MONTEREGIAN HILLS.

AUGUST 5TH—6TH.

Leader: F. D. ADAMS.
Guides: J. A. BANCROFT, Rev. Abbé GUIMONT, R. P. D. GRAHAM.
Secretary: S. W. WERNER.
Members: W. ARSCHINOW, Russia; H. BÄCKSTRÖM, Sweden; Miss F. BASCOM, U.S.A.; A. BERGEAT, Germany; H. E. BOEKE, Germany; W. CROSS, U.S.A.; H. P. CUSHING, U.S.A.; R. A. DALY, U.S.A.; A. L. DAY, U.S.A.; C. H. DINHAM, England; J. W. EVANS, England; P. GEIJER, Sweden; A. C. GILL, U.S.A.; G. W. GRABHAM, Sudan; A. S. GUINSBERG, Russia; A. HARKER, England; J. HORNE, Scotland; E. HOWE, U.S.A.; J. F. KEMP, U.S.A.; S. KOZU, Japan; A. LACROIX, France; Mme. LACROIX, France; H. LANTENOIS, Indo-China; F. LOEWINSON-LESSING, Russia; W. LOEWINSON-LESSING, Russia; Sir A. MCROBERT, Scotland; Lady R. MCROBERT, Scotland; L. MICHALOS, France; L. MILCH, Germany; L. M. PRINDLE, U.S.A.; Miss A. C. RAISIN, England; A. STANSFIELD, Canada; G. STEINMANN, Germany; E. STRATANOWITZ, Russia; J. DE SZÁDECSKY, Hungary; P. M. TERMIER, France; Mlle. M. TERMIER, France; T. TSCHERNYSCHEW, Russia; C. VISCONT, Russia; F. E. WRIGHT, U.S.A.

The excursion was arranged in order that members of the Congress might see some of the chief features of the petrographical province of the Monteregian hills.

This province is remarkable in being sharply circumscribed and consists of eight hills or "mountains," with outlying dykes and sheets that break through the nearly horizontal, Ordovician strata of the plain of central Canada. The rocks are highly alkaline, belonging to the essexite—nepheline syenite succession, with a great development of the dyke rocks consanguineous to this series.

The party visited two of the mountains, Mount Royal and Mount Johnson, and the examination occupied two days. On the first day Mount Royal was visited. In the morning the party met at the Students' Union of McGill University, and walked through the southern campus, which is underlain by glacial drift overlying Trenton limestone, to the Redpath Museum, where maps of Mount Royal were exhibited, as well as a model showing the chemical composition of the rocks of this petrographical province. The party then commenced the ascent of Mount Royal, making the first stop at the "Reservoir Extension" where the Trenton limestone, dipping at a very low angle to the south, is cut by a large number of dykes of camptonite, monchiquite, tinguaite, etc. From this point the road ascended over the basset edges of beds of Trenton limestone, showing more or less alteration, to an exposure of highly altered Utica shale overlying the Trenton. Exposures of the essexite were examined near the "Look-Out," where the rock is coarse in grain and varies considerably in texture from place to place. Other large exposures of the essexite were seen north of the "Look-Out" where they display the characteristic weathering of that rock, and where dykes similar to those mentioned above cut the essexite itself. When the atmosphere is clear an excellent view can be had from the "Look-Out" over almost the entire area of the Monteregian hills. Unfortunately, however, on the day of the excursion the smoke from the city partly obscured the landscape, although the nearer portions of the plain traversed by the St. Lawrence, with the mountains of Montarville and Beloeil were well seen.

The party then continued through the Roman Catholic cemetery on Mount Royal, where the nepheline syenite breaks through the essexite and holds many angular inclusions of it. Descending the steep northern slope of the mountain, the party had an excellent view over the plain to the north, the escarpment marking the margin of the Canadian Shield standing out clearly on the horizon. At the foot of the slope, at the quarry known as Forsyth's or the Corporation quarry, the Trenton limestone was seen in contact with the nepheline syenite which, here, also holds many fragments of the essexite, the whole complex being cut by a swarm of dykes. The limestone is intensely metamorphosed by the nepheline syenite, gradually losing its blue colour as the contact is approached and at the contact being altered to a coarse white marble. Dykes of camptonite (several varieties), tinguaite, monchiquite, nepheline syenite aplite, etc., were examined. The nepheline syenite in this locality was for many years quarried for the purpose of obtaining road metal for the streets of the city of Montreal.

An interesting occurrence of breccia at Mount Royal heights was next examined. The breccia is formed by a sheet of camptonite breaking through a shattered series of beds of Trenton limestone. The limestone fragments are thickly crowded together, and are seen to have been more or less altered by the heat of the enclosing camptonite. They are in part recrystallized, although in many of them the Trenton fossils can still be distinctly recognized. From this point the party returned to Montreal in a special car, and took lunch together at the McGill Students' Union.

After lunch the party went by motor cars to the quarries of Morrison & Co., and Rogers & Quick, at the eastern outskirts of the city. In them an immense horizontal sheet of tinguaite is opened up and worked for road metal and for the manufacture of concrete. The rock is very fresh. It is rich in nosean, and also holds rinkite, lavenite, rosenbuschite and other rare minerals. At one point the dyke which fed the sheet had been laid bare by the quarrying operations, and its relation to the sheet could thus be distinctly seen.

The party then crossed the city in their motor cars to the River St.

Lawrence, where they took passage in a ferry to St. Helen Island. Here the remarkable conglomerate or breccia which forms the greater part of the island was examined. The conglomerate was found to contain not only fragments of all the underlying stratified succession down to and including the Laurentian gneiss, but also large masses of highly fossiliferous limestone of Upper Silurian and Devonian ages, i.e., of strata much more recent than any which are now found in place in this part of Canada. The inclusions of this newer limestone have evidently sunk down into the magma from strata of Upper Silurian and Devonian ages, which at one time overlay the Ordovician succession there, but which have since been removed by erosion. The party then returned to Montreal where they spent the night.

The next day was devoted to an excursion to Mount Johnson, another of the Monteregian hills, which rises from the plain 35 kilometres south-east of Montreal. A special train was taken at 9 a.m. which, leaving Bonaventure station of the Grand Trunk railway and, crossing the St. Lawrence by the Jubilee bridge to St. Lambert, continued across the plain to the foot of Mount Johnson. This mountain is much smaller than Mount Royal and is elliptical in outline. It measures 1,066 by 761 metres at its base and is 267 metres high. It is a small but typical plug of igneous rock cutting vertically through a series of horizontal shales which at the contact it alters to typical hornstones. The intrusive mass affords a most striking example of magmatic differentiation. The outer portion next to the hornstone collar is pulaskite—a rather coarse-grained, white, alkali syenite containing a little nepheline and corresponding to the nepheline syenite of Mount Royal. The syenite forms a relatively narrow zone, and passes rather rapidly through a transitional rock into the essexite, which forms the mass of the mountain and which, towards the centre of the intrusion, becomes an olivine essexite.

Leaving the train at the foot of Mount Johnson, the party first examined the hornstone collar exposed in the maple wood about the base of the mountain. On the lower slopes large exposures of the typical pulaskite were found. Having examined these the party climbed the very steep face of the hill, examining excellent exposures of the transitional rock before mentioned, to the typical olivine-free essexite, and thence to the summit of the mountain where large glaciated surfaces of the somewhat finer grained olivine-bearing essexite of the central portion of the mass were found.

From the summit of Mount Johnston a fine panoramic view was obtained over the adjacent portion of the great plain of central Canada. On the horizon to the west, the Adirondack mountains could be seen, in the State of New York. Between these and Mount Johnson the Richelieu river could be traced from its source in Lake Champlain, northward by St. Johns and Chambly, to its junction with the St. Lawrence. The other mountains of the Monteregian group, Mount Royal, Montarville or St. Bruno, Belœil, Rougemont and Yamaska, were in full view, rising abruptly from the surface of the plain.

The party then descended the eastern slope of the mountain to large quarries in which essexite has been worked at this locality. Here lunch was served. In these quarries evidences of the vertical upward movement of the essexite magma in the plug were excellently seen, the flow structure being clearly displayed on the great quarry walls.

Very few dykes are found in association with the intrusion at Mount Johnson, the mountain in this way differing in a striking manner from Mount Royal on whose sides swarms of dykes are found almost everywhere. The most important dykes which occur on Mount Johnson are those cutting the essexite at the quarry just mentioned. Of these a large dyke of phonolite and one of a spheriodal tinguaite may be especially mentioned.

The party then continued their descent by the quarry road to the train and reached Montreal late in the afternoon.

F. D. ADAMS.

Excursion A 8.

MINERAL DEPOSISTS OF THE OTTAWA DISTRICT.

AUGUST 4TH–7TH.

Leader: J. STANSFIELD.
Secretary: M. E. WILSON.
Members: H. BECK, Germany; A. R. CROOK, U.S.A.; H. S. DE SCHMID, Canada; T. FLORES, Mexico; S. FOSLIE, Norway; A. C. LANE, U.S.A.; E. T. MELLOR, South Africa; Sir H. A. MIERS, England; P. P. PIATNIZKY, Russia; E. POITEVIN, Canada; J. B. PORTER, Canada; H. C. F. SCHULZE, Germany.

August 4. The excursion left Place Viger railway station, Montreal, at 8 a.m., for Buckingham. Lunch was served at the Alexandra hotel, and immediately afterwards the party left in carriages for the Emerald mine. Typical Laurentian scenery was presented to view on the way.

At McGuire's pit, where the first halt was made, an interesting discussion was engaged in which showed that conclusions reached at one point as to the relative ages of the rocks might be exactly reversed at another point only a few yards distant. The diorites cut by the pegmatite veins and the richly garnetiferous gneisses near the Emerald mine were next examined with a view to determining whether or not they were of sedimentary origin. At the Murray pit the mode of occurrence of the apatite and the size and shape of the ore bodies were noted, the material on the dumps furnishing the best opportunity for collecting the different minerals and for studying their relations to one another. On the southern hill other garnetiferous gneisses and quartz-rich gneisses were seen in complex relationship with pegmatites and diorites. Before leaving the hill a good example of one of the diabase dykes of the region was examined.

The return journey to Buckingham was made by river steamer, the point of embarkation being only a stone's throw from the old wharf from which the apatite was shipped in former days. The many turns in the channel of the Lievre river viewed by the waning light of the summer evening gave a constant charm to the voyage. Buckingham was reached at 6.30 p.m. and the evening was spent in a leisurely tour through MacLaren's mills, Mr. MACLAREN kindly throwing the mills open to our inspection and personally conducting us through them and explaining the various stages of the process of manufacturing wood pulp from the rough logs.

Tuesday, August 5.—The party visited the Walker mine under the guidance of Mr. H. P. H. BRUMMELL, who had charge of the mine during its most active development and was consequently able to give much information as to the mode of occurrence of the graphite and the dimensions of the ore-bodies.

The exposures immediately to the north of the main pit showed the Grenville limestone highly metamorphosed and folded and carrying a band of graphite one foot in width, the whole lying below a capping of massive gneiss which shows no indications of folding. Between the two could be followed, with difficulty, the sheet of enstatite-gabbro previously described by OSANN. The small pit 600 feet north of the main pit proved to be a point of considerable interest. Here a smooth mass of pegmatite was seen pitching steeply to the south at the northern end of the pit, while at the southern end gneisses with vertical banding occurred. The ore had been removed from the smooth surface of the pegmatite and in one place the pegmatite had been broken through, revealing the gneiss below and showing that the pegmatite was little more than a foot in thickness. The most satisfactory explanation of the form of the pegmatite vein appeared to be that it had a shape similar to that of the saddle-reefs of Bendigo, having possibly been intruded along a previously formed anticline, the graphite ore being formed at the upper surface only of the pegmatite. At a point where the pegmatite cuts limestone it was found to bear scapolite. The hill above the mill showed a typical occurrence of Grenville limestone and igneous Pre-Cambrian gneisses. The latter showed the intimate and not easily decipherable relations that often obtain between different rock types in this district.

After lunch an exposure of folded, impure Grenville limestone was visited at the fall on the Lievre river. Occasional angular blocks of foreign material seen in the limestone were considered to be the fractured remnants of dikes or tongues of igneous rocks which were ruptured at the time the limestone became folded.

The Dominion mine was reached early in the afternoon. An examination of the country rock and ore-body at the main pit, so far as this was possible in the drowned state of the pit, showed that the ore was an impregnated pyroxenite, and that the graphite was associated with a gabbro, of which varieties ranging from anorthosite to pyroxenite were met with.

A very interesting section showing brecciated Grenville limestone and recrystallized sediments (cordierite-sillimanite-garnet-gneiss), was exposed at another small pit, where the ore-body evidently followed the dip of the beds, and no connection with an igneous mass could be established.

By the courtesy of Mr. BRUMMELL the party was conducted through the mill where the "dry process" for extracting graphite is well exemplified.

In the evening the party left Buckingham by train for Ottawa.

Wednesday, August 6.—Proceeding by Canadian Pacific railway to Kirk Ferry, the party crossed Gatineau river by ferry and walked to the Nellis mica mine, stops being made on the way to examine the granite-gneisses and the impure Grenville limestones.

At the Nellis mine a vein had been uncovered at the surface to show the mode of occurrence of the mica and the methods adopted in prospecting. A shaft following the same vein to a depth of thirty feet enabled the party to study the variations in the vein, which were beautifully illustrated. At the south end of the hill other characteristics of the veins were observed, including a general similarity of strike, pinching out at the surface and combs of pyroxene crystals on the vein walls; one of the two examples of veins not following the general strike common to the hill was also seen. Other veins were examined that further illustrated the mode of occurrence of the mica and its relation to other vein minerals.

After lunch the Chute on Gatineau river was visited and the return trip was made by train from Kirk Ferry to Ottawa. Leaving Ottawa at 10.45 p.m. the party arrived in Toronto at 7 a.m. on Thursday, August 7th.

J. STANSFIELD.

Excursion A 9.

MINERAL DEPOSITS NEAR KINGSTON.

AUGUST 4TH 7TH.

Leader M. B. BAKER.
Associate leader: W. NICOL.
Secretary: S. KIRKPATRICK.
Members: M. EELOWSKY, Germany; H. BOWMAN England; L. E. T. DAHLBLOM, Sweden; J. DRUGMAN, England; E. DUPUY DE LOME, Spain; B. GOSSNER, Germany; C. A. HANIEL, Germany; B. HOBSON, England; A. E. KITSON, British West Africa; P. KUKUK, Germany; M. LUBOSCHINSKY, Russia; H. M. LUTTMAN-JOHNSON, England; A. MARIN Y BERTRAN DE LIS, Spain; S. G. MARTIUS, Germany; H. M. MITSCHERLICH, Germany; G. M. PART, England; W. PAULCKE, Germany; F. L. RANSOME, U.S.A.; Miss A. RATHGEN, Germany; J. SAMOJLOFF, Russia; H. S. SJÖGREN, Sweden; O. P. SOUSTCHINSKY, Russia; N. TILMANN, Germany; W. VERNADSKY, Russia.

(See Guide Book No. 2, pp. 112-139.)

Excursion A 10.

PLEISTOCENE AT MONTREAL, COVEY HILL AND OTTAWA.

AUGUST 4TH–7TH.

Leader: J. W. GOLDTHWAIT.
Secretary: L. H. COLE.
Members: J. BARRELL, U.S.A.; Rev. P. DUPAIGNE, Canada; W. A. JOHNSTON, Canada; J. KEELE, Canada; H. B. KÜMMEL, U.S.A.; R. LACHMANN, Germany; L. DE LAMOTHE, France; F. LEVERETT, U.S.A.; P. LORY, France; T. PAREDES, Mexico; S. POWERS, U.S.A.; E. ROMER, Austria; F. URBINA, Mexico; T. F. W. WOLFF, Germany; J. B. WOODWORTH, U.S.A.

The greater part of the first day, Monday, August 4th, was spent in Montreal. Leaving the local headquarters of the Congress at 9 o'clock, the party entered Mount Royal Park by way of the Côte des Neiges road. Just outside the gate attention was drawn to a section which showed very poorly stratified, stony, marine beds resting on a rather steeply sloping rocky surface, an illustration of sea margin deposit where the waves have little opportunity to build actual beaches. Proceeding next to the gravelly slope near the foot of the Park Slide, the members stopped to study spits or beaches which partially enclosed a shallow lagoon at a time when the sea stood near the 570-foot contour. Through the courtesy of Mr. HENDERSON, the park ranger, the party was enabled to collect shells of *Saxicava rugosa* (*arctica*) from a freshly excavated ditch in the highest of these beaches. The delicate form of these spits as compared with great sea-cliffs and terraces of extinct shorelines in other regions caused comment, but their littoral origin was not questioned. It was pointed out that the land must have been rising rapidly from the sea at this stage of submergence, inasmuch as the spits are short and their bulk small although the conditions of slope and supply of beach material from adjacent cliffs were favourable for rapid beach construction.

Going on along the Park drive, past the ranger's house to the corner, and taking the turn toward the west, the party found a freshly dug trench beside the road in which well worn gravels were to be seen on the surface up to 600 feet above sea level. These had not been seen by any member of the party until the day before the excursion. The possibility of their marine origin was admitted, but regarded as doubtful for two reasons: (1) deeply decomposed rock, at an altitude of scarcely 600 feet, in a quarry at the rear of the Mount Royal cemetery, nearby, shows no sign of washing on the surface, where waves should have left their mark; and (2) the gravels above the level of the 570-foot beach, so far as observed, do not display typical wave-built form. At the corner of the Park road already mentioned, however, notice was called to a short, smooth-topped ridge of gravel which connects the main eminence of the mountain with a 665-foot hill in such a way as to suggest a land-tied island, with the gravel bar standing at about 625 feet. Some members of the party were inclined to accept this as a marine form, although they recognized the probability that local deposits of gravel took place just before the actual entrance to the sea, in irregular pools along the thinning edge of the ice-sheet, where wave action was impossible.

On the way back to the city the party visited the Peter Redpath Museum, where Mr. ARDLEY, the curator, showed them Sir WILLIAM DAWSON'S unrivalled collection of post-pleistocene shells and skeletons from the St. Lawrence valley. Lunch was taken at the Edinburgh café. Immediately after lunch a number of the members went by street car to the Papineau Avenue quarries, where they saw a section of *Saxicava* gravels and boulder clay overlying a striated surface of Trenton limestone.

Late in the afternoon the entire party left by regular train for Hemmingford, where they found lodgings at Orr's Hotel. In the evening the members were welcomed by the people of the village at an outdoor social on the lawn beside the Episcopal church. Mr. ROBB, member of parliament from the district, and ministers of the local churches spoke words of greeting and good will. For the visiting party Professor WOODWORTH responded, explaining the purposes of the party in coming to Covey Hill.

On Tuesday the party set out after breakfast in wagons for Covey Hill, ten miles away. A short stop was made at a gravel pit just south of the village, in order that the visitors might collect *Saxicava* shells. A few valves of *Macoma Groenlandica* were found, also, at a roadside post hole near Frontier settlement. Arriving at the Covey Hill Methodist church, all left the wagons, in order to set foot on the fine beaches of sandstone slabs which cross the road at that point. The distant view northward across the St. Lawrence lowland, from here, included the island-mountains of the Monteregian group, and served well to carry the observations of the preceding day over to those of the day at Covey Hill. The extraordinary strength of these beaches, in contrast to their counterparts on Mount Royal, was regarded as a result of the kind of material available rather than of heavier surf or a longer stand of the sea at the more southerly locality.

At Covey Hill Corners a short walk down the road northward to a gravel pit on Mr. COLE'S property served to show the party that the beach ridges so plainly developed below 525 feet terminate abruptly at that height. Shallow cuts in the ground and post-holes by the roadside showed till with no covering of wave-washed material on the slope above the 525-foot beach, and rolled gravels everywhere below it. The conclusive character of this evidence was accepted by all present. Later, while continuing the ascent of Covey Hill, the members looked for signs of wave work at higher levels, but saw none.

Luncheon was served to the party by the ladies of Covey Hill in a pretty grove near the Sutton place. The Hon. Mr. Robb and other guests were present. A tour of the famous "Gulf" and gorge occupied most of the afternoon. Entering the valley of the ancient outlet of glacial Lake Iroquois near its head, at the "upper lake," the party visited the cliff which is thought to mark the site of an extinct Niagara. The narrowness of the gorge at this point caused some discussion of the merits of the theory that it lay along the course of a river which carried the entire discharge of the great Lake Iroquois; and to account for it a possible line of auxiliary drainage, beneath the ice, around the north side of Covey Hill, was suggested. Professor Woodworth acted as guide on this part of the excursion. At the Gulf, opportunity was given to descend the side wall of the gorge and thus secure a view of it from the floor below. Two of the members, Messrs. Leverett and Goldthwait, made a cross traverse of the old outlet floor, with an aneroid barometer, in the vicinity of the gulf, in order to determine how wide and deep the channel might have been. In the width of over a quarter of a mile the depth of this channel seems to have been less than twenty feet, except possibly at the place where the present gorge occurs.

On returning to Covey Hill Corners at 5 o'clock, the members of the party were the guests of Mr. L. H. Cole and his mother, at afternoon tea, on the lawn beside the Cole cottage. The ten mile ride to Hemmingford was completed in time for a late supper at the hotel.

On the return to Montreal, early Wednesday morning, the party was reorganized into two divisions. One, consisting of Messrs. Leverett, Lachmann, Paredes, Urbina, Wolff, Cole, and Johnston proceeded to Ottawa; the other, including Messrs. Dupaigne, Goldthwait, Keele, Kümmel, de Lamothe, Powers, Romer and Woodworth went to Rigaud Mountain. Messrs. Barrell and Lory remained at Montreal. Those who spent the afternoon in Ottawa gave special attention to the ridges of coarse bouldery drift in Hull, the origin of which has been disputed. Messrs. Leverett and Wolff, as spokesmen for the party, reported that they were inclined to the opinion of Chalmers that these ridges are not moraines, but deposits from floating ice coming down the Ottawa and Gatineau rivers during the period when the valley was emerging from the sea. This view is important in that it makes it unnecessary to suppose that the ice sheet readvanced at Hull after the underlying marine clays of the Champlain stage had been deposited. The party which went to Rigaud Mountain spent the day inspecting the boulder beaches at the Devil's Garden,—mentioned by Dawson in the *Geology of Canada*, p. 896. From near the top of the mountain, about 600 feet above the sea, down almost to the level of the shrine, at 450 feet, the slope is covered with rolled boulders to a depth of at least ten feet, over several hundred acres. Twenty or thirty distinct ridges, with even crestlines and forward slopes of characteristic form, indicate that the boulders were arranged by the waves during the period when this mountain was an island in the sea. Descending from the uppermost ridges towards the lowest ones, one sees a steadily decreasing size and increasing roundness of the boulders. Although no marine shells have been found in the deposit, the occurrence of the beaches, up to but not above the 600-foot contour, confirms the view that they, like those on Mount Royal, are marine. The bouldery structure of the Rigaud beaches, so astonishing to one who has just visited the weak sand spits of Mount Royal, illustrates how the character of the available material determines the topographic strength of beaches.

The two divisions of the party met again on Wednesday evening at Ottawa, and proceeded by night train to the assembly of the Congress at Toronto.

J. W. GOLDTHWAIT.

Excursion A 11.

ORDOVICIAN AT MONTREAL AND OTTAWA.

AUGUST 4TH—7TH.

Leader: P. E. RAYMOND.
Secretary: E. D. INGALL.
Members: C. E. GORDON, U.S.A.; Miss E. GREGORY, U.S.A.; Miss A. HEINE, U.S.A.; O. HOLTEDAHL, Norway; W. F. HUME, Egypt; A. M. MILLER, U.S.A.; T. C. NICHOLAS, England; C. SCHUCHERT, U.S.A.; H. W. STILLE, Germany; E. O. ULRICH, U.S.A.

The party assembled at the Place Viger station in Montreal on Monday morning, August 4, and proceeded by train to St. Martin Junction where the extensive limestone quarries in the Chazy were visited. From the quarries the party walked to the railway cutting at Park Laval. At both localities considerable numbers of fossils were obtained, particularly the spherical cystid, *Malocystites murchisoni.* At the quarries, the members of the party were especially interested in the strata which were almost entirely made up of cystid remains.

In the afternoon the party divided, one division visiting St. Helen Island, and the other going to the exposures of the lower Trenton in the quarries at Mile End. There was considerable discussion as to the exact ages of the various "Lowville," "Black River," and "Trenton" formations exposed at the latter place, but no definite conclusions were reached.

In the evening the party proceeded to Ottawa.

Tuesday morning was devoted to the exposures of the Trenton in Hull and Ottawa, and Drs. STILLE and HOLTEDAHL were especially interested in the cherts of the lower (Crinoid) division of the Trenton. The cherts occur as thin nodules or plates parallel to the bedding, and it was brought out that the bedding planes could also be distinguished in the cherts themselves. The members were also interested in the contorted and unevenly bedded strata of the cherty layers, and the immense boulder beds which formed the overburden of the quarries. Many fossils were obtained from the "*Prasopora*" beds near their contact with the "*Tetradium*" beds at the axe factory in Hull.

In the afternoon the exposures of Utica and Collingwood strata near Cummings Bridge were visited and many fossils secured, largely through the instrumentality of Mr. J. E. NARRAWAY of the local committee, who acted as guide, and who turned up many specimens of *Triarthrus spinosus.* From Cummings Bridge the party proceeded to Division Street, to see the upper Trenton or Picton beds, and were fortunate in finding very good specimens of *Strophomena trilobata*, showing the interiors of the valves. This species is rare about Ottawa. It may be noted in passing that this may be the last international party which will be able to collect at this old quarry, which is well known among palaeontologists, for two buildings had been erected within its limits between the time of the writing of the guide book and the visit of the party, and the entire ground will probably soon be covered.

Wednesday morning was spent at the Victoria Memorial Museum, where Mr. LAWRENCE M. LAMBE and Mr. W. J. WILSON very kindly assisted in explaining the collections.

In the afternoon the party again divided into two sections, one taking a general view of the region by visiting Britannia and Rockcliffe, and the other going to Mechanicsville to collect fossils from the Lowville and Leray.

In the evening the party left for Toronto.

P. E. RAYMOND.

Excursion A 12.

THE PALÆOZIC FORMATIONS OF SOUTH-WESTERN ONTARIO.

AUGUST 4TH—6TH.

Leader: W. A. PARKS.
Guides: C. R. STAUFFER, M. Y. WILLIAMS, H. V. ELLSWORTH, A. J. GALBRAITH.
Secretary: W. H. MCNAIRN.
Members: K. ANDRÉE, Germany; J. DEPRAT, Indo-China; M. J. GOLDMAN, U.S.A.; J. OPPENHEIMER, Austria; C. S. PROSSER, U.S.A.; P. PRUVOST, France; J. G. ROTHERMEL, U.S.A.; A. J. RIEDEL, Germany; E. STOLLEY, Germany; T. G. SKOUPHOS, Greece; Miss M. TALBOT, U.S.A.; R. ZUBER, Austria.

The party left Toronto by special car at 8 a.m., Monday, August 4, and proceeded directly to Hagersville, where they were received by the Hagersville Local Committee and taken in automobiles to the various points indicated in the guide book. The excursionists were particularly impressed by the numbers of fossils on some of the blocks of Oriskany sandstone and by the facility with which beautifully silicified fossils could be collected from the Onondaga débris in the fields north of Hagersville. Dinner was served by the courtesy of the Alabastine Company in the gypsum mine at Caledonia.

During the night the car was taken to Thedford and on Tuesday the programme as indicated in the guide book was followed exactly. The kindness of the Arkona committee in providing automobiles and in serving luncheon in Rock Glen was much appreciated. The profusion of fossils in the Hamilton formation exposed along the banks of the Aux Sables river attracted particular interest.

During the night the car was taken to Guelph and the following day was spent on the Guelph formation at Guelph, Hespeler and Galt. Some disappointment was expressed at the difficulty of obtaining well preserved fossils but all were delighted with the profusion of *Megalomus* in the quarries at Galt. The Guelph Local Committee provided automobiles for the day and entertained the excursionists at luncheon. The party returned to Toronto in the evening.

W. A. PARKS.

Excursion B 1.

NIAGARA FALLS.

AUGUST 12TH.

It was taken for granted that all the members of the Congress who had not already visited Niagara falls with Excursion A 4 would wish to do so during their stay in Canada, and August 12 was set down as a convenient day for the purpose, though no formal programme was arranged and no definite leader was appointed. Many of the members used the day for this purpose, some crossing Lake Ontario by the steamer at 7.30 a.m., others at 9 o'clock. Although leaders had not been appointed, some of the excursionists accompanied Mr. F. B. TAYLOR, and others Dr. J. C. SPENCER; many, however, found their own way to points of interest.

A. P. COLEMAN.

Excursion B 2.

DON VALLEY AND SCARBORO' HEIGHTS.

AUGUST 12TH.

The interglacial beds at Toronto are best exposed at the two localities mentioned; and the Don valley was visited in the morning and Scarboro' Heights in the afternoon, under the guidance of Dr. A. P. COLEMAN, Mr. H. L. KERR and several assistants. The excursion to Don valley was made by street car and on foot and was participated in by about 65 members. The relationships of the inter-Glacial stratified clay and sand to the boulder clay below and above were studied and numerous shells and some wood were collected. Above the second sheet of boulder clay, barren, stratified clays were seen, formed probably while the ice-front was not far distant. The terrace of glacial Lake Iroquois was followed up to its old shore cliff in the northern part of Toronto, giving a good idea of an abandoned lake beach.

Owing to the unusually high water in Lake Ontario it was impossible to walk along the foot of Scarboro' cliffs, as had been planned; and, instead, it was arranged that the excursionists should be taken to Scarboro' Heights by launches. Unfortunately many more members than had applied for the excursion arrived on the wharf, and as the launches would hold only the 65 which had been arranged for, many had to go by street and suburban cars.

The main party in the launches encountered rough weather after leaving Toronto bay, and owing to the heavy sea on Lake Ontario it was thought unwise to land under the cliffs. The few who did so got wet in landing from the small boats.

Though no opportunity was given for close study of the section, the fine inter-Glacial valley of the "Dutch Church," a mile wide on top and 150 feet deep, could be distinctly seen, with the sheet of overlying boulder clay which dips into it and fills it. The so-called "church" is carved by rain and stream erosion from the resistant mass of boulder clay in the centre of the old valley.

The party which travelled by electric cars reached the Dutch Church from the north; but, owing to the delay caused by the change of plans, had little time for close study of the section.

A. P. COLEMAN.

Excursion B 3.

THE PALÆOZOIC FORMATIONS AT HAMILTON, ONTARIO.

AUGUST 8TH

Leader: W. A. PARKS.

Guides: H. V. ELLSWORTH, MISS ALICE E. WILSON.

Secretary: H. V. ELLSWORTH.

Members: E. M. ANDERSON, Scotland; K. ANDRÉE, Germay; A.
BIGOT, France; A. M. CAMPBELL, Canada; A. R. CROOK, U.S.A.;
H. P. CUSHING, U.S.A.; J. DEPRAT, Indo-China; E. DUPUY DE
LÔME, Spain; R. FABREGA, Spain; Abbé C. R. GUIMONT, Canada;
C. A. HANIEL, Germany; C. HARTNAGEL, U.S.A.; J. A. L. HENDER-
SON, England; P. E. HOPKINS, Canada; J. E. HYDE, Canada;
A. KEITH, U.S.A.; C. R. KEYES, U.S.A.; A. MARIN Y BERTRAN
DE LIS, Spain; A. M. MILLER, U.S.A.; B. L. MILLER, U.S.A.;
E. S. MOORE, U.S.A.; G. M. PAUT, England; W. PAULCKE, Ger-
many; H. DE PAYERIMHOFF, France; C. S. PROSSER, U.S.A.; P.
PRUVOST, France; P. E. RAYMOND, U.S.A.; C. SCHUCHERT, U.S.A.;
W. E. SIMPSON, Mexico; T. G. SKOUPHOS, Greece; C. R. STAUFFER,
U.S.A.; P. STEPANOV, Russia; H. STILLE, Germany; E. E. TELLER,
U.S.A.; N. TILMANN, Germany, L. P. TOLMAČEV, Russia; W. H.
TWENHOFEL, U.S.A.; E. O. ULRICH, U.S.A.; F. R. VAN HORN,
U.S.A.; H. S. WILLIAMS, U.S.A.; M. Y. WILLIAMS, Canada; R.
ZUBER, Austria.

The excursion left Toronto at 8 a.m., Friday, August 8, and proceeded directly to Grimsby where the programme as indicated in the guide book was carried out. Luncheon was served in the Village Inn at Grimsby after which the party left by special car for Hamilton. The Local Committee met the party with automobiles and conveyed them to the points at which the Palæozoic section is best exposed. The veteran local collector, Col. C. C. GRANT, accompanied the party and greatly assisted in explaining the formations to the visitors. Some discussion arose, particularly among the American geologists, as to the stratigraphic value of the recently proposed *Cataract* formation. The evidence is too perfect to permit doubt of the position of the Cataract series below the sandstone with *Arthrophycus*, but it was maintained that these beds are not a stratigraphic unit and consequently will not suffice for the removal of the Cataract from the Medina. On the whole, however, the succession of strata as indicated in the guide book met with approval. Some discussion also arose as to the relationship of the Lockport chert beds at Hamilton to the Encrinal limestone exposed in the top of the section at Grimsby.

In the early evening a visit was paid to the museum of the Hamilton Association where the excellent series of local fossils collected by Colonel GRANT was examined. The Hamilton Local Committee entertained the excursionists at dinner in the Hamilton Club where a very pleasant evening was spent.

W. A. PARKS.

Excursion B 4.

THE SILURIAN SECTION AT THE FORKS OF THE CREDIT RIVER, ONTARIO.

AUGUST 12TH.

Leader: W. A. PARKS.
Guides: J. STANSFIELD, H. V. ELLSWORTH.
Secretary: J. STANSFIELD.
Members: H. P. CUSHING, U.S.A.; E. DUPUY DE LÔME, Spain; C. HARTNAGEL, U.S.A.; B. HOBSON, England. E. V. D'INVILLIERS, U.S.A.; A. C. LANE, U.S.A.; A. MARIN Y BERTRAN DE LIS, Spain; F. B. PECK, U.S.A.; O. F. PFORDTE, U.S.A.; A. F. FOERSTE, U.S.A.; A. RENIER, Belgium; Madame A. RENIER, Belgium; C. SCHUCHERT, U.S.A.; P. STEPANOV, Russia; E. E. TELLER, U.S.A.; I. P. TOLMAČEV, Russia; E. O. ULRICH, U.S.A.; G. R. WIELAND, U.S.A.

The excursion left Toronto by Canadian Pacific railway at 7.20 a.m., Tuesday, August 12, and left the train at Cataract Junction. Some time was spent there in collecting from the Cataract shales and some discussion arose as to whether the heavy bed at the bottom of the Lockport should be ascribed to the Lockport or to the Clinton.

At noon the party was driven in carriages to the beautiful club house of the Caledon Mountain Trout Club, where luncheon was served. In the afternoon some of the party ascended the escarpment, whence a magnificent view was obtained over the rolling morainic lands to the east. The greater portion of the party spent the afternoon in collecting from the Cataract shales and limestones along the Belfontain branch of the Credit river. Some interesting graptolites, not hitherto recorded from the formation, were obtained by E. O. ULRICH and others. Dr. RENIER manifested great interest in certain obscure plant remains which were also found at this point.

The party returned to Toronto in the evening.

W. A. PARKS.

Excursion B 5.

MORAINES NORTH OF TORONTO.

August 9th.

Leader: F. B. Taylor.

Members: H. Ar vski, U.S.A.; J. W. Goldthwait, U.S.A.; R. R. Rice, U.S.A.; F. Leverett, U.S.A.; S. G. Martius, Germany; L. de La Mothe, France; J. L. Rich, U.S.A.; E. Romer, Austria; A. Schenck, Germany; E. Stratanovitch, Russia; W. Upham, U.S.A.; T. F. W. Wolff, Germany.

The morning of August 9, was rainy. onsequently only twelve members met the leader at the Radial station o North Yonge Street, and took the 9.30 car for Bond lake. The till in the fresh cutting along the road south of Bond Lake was found to be light coloured, rather soft and loose textured distinctly the newer till. Going down the northward slope to Schomberg Junction the deposits are mainly sandy and silty and are largely stratified, as though laid down in the edge of still water probably an early, temporary stage of Lake Lundy. A question was raised as to whether the flat valley between the moraines to the north and south at Schomberg Junction, is a scoured river bed or an original, unmodified till plain. There are no evidences of scour on the valley floor west of Willcocks lake, but running water, bearing sand and gravel, entered the valley northeast of the lake and appears to have built the barrier which retains the lake on that side. The lake fills a very shallow depression in the plain. The party had luncheon at a picnic ground at the east end of Willcocks lake, where a small and somewhat dilapidated pavilion afforded shelter from the rather cold wind.

After luncheon the party walked north, leaving the south moraine and crossing the flat valley floor northeast of the lake. Here an extensive deposit of sand and fine gravel fills the valley from side to side, in the form of a low, delta-like deposit, forming the retaining barrier, and causing the lake to drain west through a sluggish stream, although within a mile and a half to the northeast there is a sharp descent of 100 feet or more to streams which flow north to Lake Simcoe. North of the flat and the lake, the party crossed a part of the northern moraine with basins and other typical features of terminal moraine topography. This moraine is strongly developed. The country north of it is considerably lower than the plain at Schomberg Junction. Descending the north slope, the road cuts through deep deposits of sand and fine gravel which might be regarded as outwash if the ice face north while building the moraine. But near the cross roads, a mile and a half east of the cemetery south of Aurora, a kame was visited (and others were in sight to the east) which shows that the ice in building this moraine, faced to the south. The kames are somewhat elongate in form, almost like eskers, and evidently led southward to the moraine and not northward away from it. The gravels which extend westward along the north or rear slope of the moraine were seen again at the cemetery south of Aurora; but the point from which their relation to the moraine could be seen best was not visited for lack of time. It is almost certain that the drift in the vicinity of Bond Lake reaches a depth of 1,000 feet or more. The greater part of this mass is undoubtedly of pre-Wisconsin age, the newer moraines being set upon the top of the older mass. The south moraine was built by ice moving north and northwest from the basin of Lake Ontario, the north moraine by ice moving south and southwest from the basin of Lake Simcoe. At Schomberg Junction a till plain only one mile wide was left between two moraines. Evidence in other parts of the region indicates that the south moraine is of slightly later date than the north moraine.

Returning, the party boarded the car at the cemetery south of Aurora and reached Toronto at 5.30 p.m.

F. B. Taylor.

Excursion B 6.

MUSKOKA LAKES.

August 10th.

Leader: G. G. S. Lindsey.

Secretary: P. E. Hopkins.

Members: R. Beck, Germany; H. G. Backlund, Argentine; A. Bergeat, Germany; H. L. Bowman, England; L. E. de Buggenoms, Belgium; R. G. Carruthers, Scotland; A. D. Campbell, Canada; T. C. Denis, Canada; Mrs. Denis, Canada; C. H. Dinham, England; J. Drugman, England; E. R. Faribault, Canada; N. M. Fenneman, U.S.A.; F. Frech, Germany; Mrs. Frech, Germany; S. McL. Gardner, Scotland; R. P. D. Graham, Canada; M. I. Goldman, U.S.A.; Miss A. Goldman, U.S.A.; Miss A. Grutterink, Holland; P. J. Holden, U.S.A.; E. O. Hovey, U.S.A.; J. P. Howley, Newfoundland; Mark Hurll, Scotland; J. M. Hurll, Scotland; R. B. Hobson, England; G. F. Kunz, U.S.A.; A. Keith, U.S.A.; R. Lachmann, Germany; H. M. Littman-Johnson, England; L. Michalon, France; Bedford McNeill, England; Mrs. McNeill, England; Sir A. McRobert, Scotland; Lady McRobert, Scotland; E. T. Mellor, South Africa; B. L. Miller, U.S.A.; L. Milch, Germany; T. C. Nicholas, England; H. de Peyerimhoff, France; A. H. Phillips, U.S.A.; G. M. Part, England; P. D. Quensel, Sweden; Mrs. Quensel, Sweden; Miss Anna Rathgen, Germany; W. E. Simpson, Mexico; Mrs. Simpson, Mexico; E. Stolley, Germany; T. de Surzycki, Russia; H. S. de Schmid, Canada; C. J. Skottsberg, Sweden; Miss M. Tyrrell, Canada; J. E. Wolff, U.S.A., B. Weigand, Germany; J. E. Woodman, U.S.A.; C. A. Welter, Germany; H. B. Wallis, England; A. G. B. Wilbraham, England; P. L. G. Zoude, Belgium.

A special train on the Grand Trunk railway with these sixty-two geologists left Toronto at 11.50 p.m. on Saturday, August 9, the party being transferred at seven o'clock next morning at Muskoka Wharf to the Muskoka Navigation Company's steamer *Sagamo*. The day was beautiful and the sail through the lovely lakes much enjoyed. The country was pronounced to be very like the lake country of Sweden.

Four of the party debarked at Beaumaris and were taken in charge by Professor John A. Brashear, of Pittsburgh, Pennsylvania, who took them in his private yacht about the lakes to Bala, where some time was spent looking at the rocks. Through the kindness of Mr. Prowse of the Beaumaris Hotel these gentlemen were lunched by him, and then Professor BUSSU-EAU took them to Port Carling, where an Indian encampment was inspected.

The remainder of the party debarked at the Royal Muskoka Hotel. Ten of the party were taken in charge by Mr. Z. A. LASH, K.C., and whirled around the lakes in his motor launch, lunching at his hospitable summer home and having an opportunity to examine the rocks.

Two gentlemen were similarly looked after by Mr. JOHN PENMAN, of Penman Isle; four by Mr. W. L. CLAUS at his Lake Joseph island, and the remainder, with the exception of four, were taken by the leader on Mr. E. R. WOOD's launch around Lakes Rosseau and Joseph. After luncheon at the Royal Muskoka Hotel an hour was devoted to the formations.

Professor BECK, C. J. F. SKOTTSBERG, MARK HUBL and Dr. HOWLEY stayed on the *Sagamo*, going on to Rosseau, where the two former had a short botanizing excursion.

The simple geology of the lakes was easily observed everywhere from the launches which sailed always among the beautiful islands of this region.

The *Sagamo* picked up all parties at various points and brought them back to Gravenhurst, whence the Grand Trunk landed them safely in Toronto at midnight on the tenth.

G. G. S. LINDSEY

Excursion B 7.

THE RICHMOND SECTION AT STREETSVILLE.

AUGUST 13TH.

Leader: J. STANSFIELD.
Guide: H. V. ELLSWORTH.
Members: P. FABREGA, Spain; A. F. FOERSTE, U.S.A.; C. HARTNAGEL, U.S.A.; J. E. HYDE, Canada; E. O. ULRICH, U.S.A.

The excursion left Toronto at 8 a.m., Wednesday, August 13. The programme as indicated in Guide Book No. 5 was carried out. The American geologists, particularly Dr. ULRICH, expressed the opinion that the whole of the section should be ascribed to the Richmond and that the lower rocks are not referable to the Lorraine.

Excursion B 8.

CLAY DEPOSITS NEAR TORONTO.

AUGUST 13TH.

A small party, under the leadership of Professor M. B. BAKER, spent the afternoon of August 12 in visiting the works and clay deposits of the Don Valley Brick Company, and the Swansea Sewer Tile Company (See Guide Book No. 6, pp. 50-53).

Excursion B 9.

LAKE SIMCOE DISTRICT.

AUGUST 11TH.

Leaders: J. W. GOLDTHWAIT, W. A. JOHNSTON.
Members: H. ARCTOWSKI, U.S.A.; H. B. KÜMMEL, U.S.A.; J. H. LEES, U.S.A.; F. LEVERETT, U.S.A.; S. POWERS, U.S.A.; P. E. RAYMOND, U.S.A.; W. R. RICE, U.S.A.; E. ROMER, Austria.

(See Guide Book No. 5, pp. 23-35.)

Excursion B 10.

August 9th and 10th.

THE MADOC AREA, SOUTHEASTERN ONTARIO.

Guide: Cyril W. Knight.

Members: J. A. Bancroft, Canada; C. P. Berkey, U.S.A.; H. L. Borgström, Finland; A. Defline, France; H. Frechette, Canada; G. W. Grabham, Sudan; A. E. Kitson, Gold Coast; C. K. Leith, U.S.A.; A. Mailhiot, Canada; W. G. Miller, Canada; P. Weiss, France; E. T. Wherry, U.S.A.; A. W. G. Wilson, Canada.

The excursion party to the Madoc area in southeastern Ontario left Toronto at 5 o'clock Friday afternoon, August 8, and arrived at the village of Madoc the same night. The next two days were devoted to geological examinations. On Saturday the party was entertained at luncheon by Mr. and Mrs. Geo. H. Gillespie.

OBJECTS OF THE EXCURSION.

Apart from two mines which were visited, the excursion had four main objects: (1) to show the general similarity between Pre-Cambrian rocks in southeastern Ontario and those in the region around Lakes Huron and Superior; (2) to show greenstone schists and pillow lavas of the Keewatin series underlying and apparently forming the basement on which the Grenville sediments were deposited; (3) to show the stratigraphic position of the Grenville series and the character and relations of the members of the series; (4) to show that a great unconformity exists between the overlying, infolded, Hastings conglomerate (Fig. 1) and the Grenville series. The following table gives the classification adopted for the Pre-Cambrian rocks in southeastern Ontario, but the time at the disposal of the Madoc excursion did not permit of the investigation of all of the relationships included in the classification.

LEGEND FOR PRE-CAMBRIAN ROCKS IN SOUTHEASTERN ONTARIO.

Post-Hastings intrusives...... Granite, diabase, gabbro, basalt.

Intrusive contact.

Hastings series.... .... Conglomerate, quartzite, slate, limestone, and their metamorphosed derivatives.

	Unconformity.
Laurentian series	Gneissoid granite and syenite
	Intrusive contact.
Grenville series	Limestones, quartzite, greywacke, slate, largely altered to various schists and gneisses.
Keewatin series	Green-schists, pillow lavas, diorite-gneiss, etc.

MINES VISITED.

In the morning of the ninth of August the party examined the Henderson talc mine, which lies on the outskirts of the village of Madoc. The deposit is found in a magnesian crystalline limestone of the Grenville series, the material occurring in great lenticular bodies, in places 40 feet wide. The

FIG. 1.—Hastings conglomerate, southeastern Ontario, showing pebbles elongated by pressure.

talc has resulted from the alteration of magnesian limestone of the Grenville series, and it was suggested by some members of the party that actinolite was first to form and that later this mineral altered to talc.

The same morning the pyrite mine of the Canadian Sulphur Ore Company near Queensboro was visited, and it was observed that the deposit occurs at the contact of a rusty schist and quartzite, near an intrusion of felsite. These rusty schists are of common occurrence in this part of Ontario, and it would seem probable that important deposits of iron pyrites may be discovered by prospecting the rusty schists which occur near igneous intrusions.

ROCKS EXAMINED ON AUGUST 9TH.

In the afternoon of the ninth of August, interesting outcrops of Pre-Cambrian rocks within a radius of about a mile of the village of Madoc were studied. The members were supplied with a detailed map of the area on a scale of 1,000 feet to the inch published by the Ontario Bureau of Mines. Immediately north of the village fragmental rocks of complex origin were examined and found to consist (1) partly of a felsite intrusion holding very numerous fragments of other rocks, including crystalline limestone, (2) partly of agglomerate, and (3) partly of crush-breccia.

About a third of a mile to the northeast of the Catholic church, beds of "conglomerate" (Fig. 2), slate and limestone were examined. The pebbles of most of this "conglomerate" consist of crystalline limestone, and some of

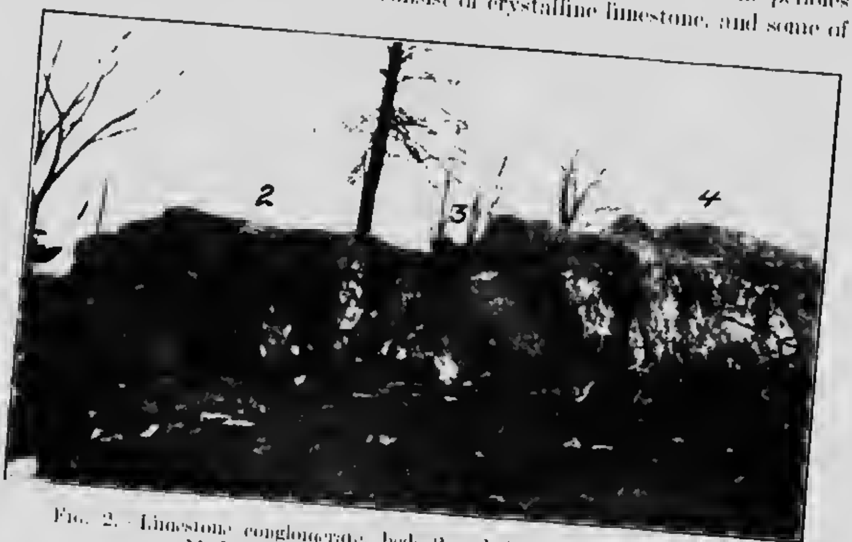


FIG. 2.—Limestone conglomerate, beds 2 and 4, interbedded with slate, Madoc, Hastings county, southeastern Ontario.

the excursionists thought that it was a crush-conglomerate formed by the brecciation of the crystalline limestone. The majority, however, considered that it was a true water-worn conglomerate, interbedded with slate and limestone.

The excursionists then went west to the Hastings road, along which they walked northerly about a mile, over steeply dipping beds of crystalline limestone, slate and other fragmental rocks, and visited an abandoned slate quarry. From there they proceeded west to lot 4 in the fifth concession of Madoc township, walking over an amygdaloidal andesite, to examine beds of "conglomerate" (Fig. 3), which are here interstratified with slate. Most of the pebbles of this "conglomerate" are crystalline limestone, the rock being somewhat similar to that mentioned in the preceding paragraph. The majority of the party was inclined to consider the "conglomerate" a true water-worn type, while others thought it was of the nature of a crush-breccia. The slate, however, with which the "conglomerate" is interbedded, is only very slightly brecciated; and it was pointed out that, if the conglomerate was formed by crushing of the limestone, the slate ought to be also crushed and brecciated. It was noted also that the "conglomerate" contains also a 12-inch bed of quartzite which shows no evidence of brecciation. On the other hand, it could be seen that the limestone "conglomerate" passes into massive crystalline limestone, which was considered by some of the party as evidence that the rock is a crush-conglomerate.

The latter rests on an amygdaloidal andesite, the plane of contact dipping about 37° to the southeast. The contact is exceptionally well

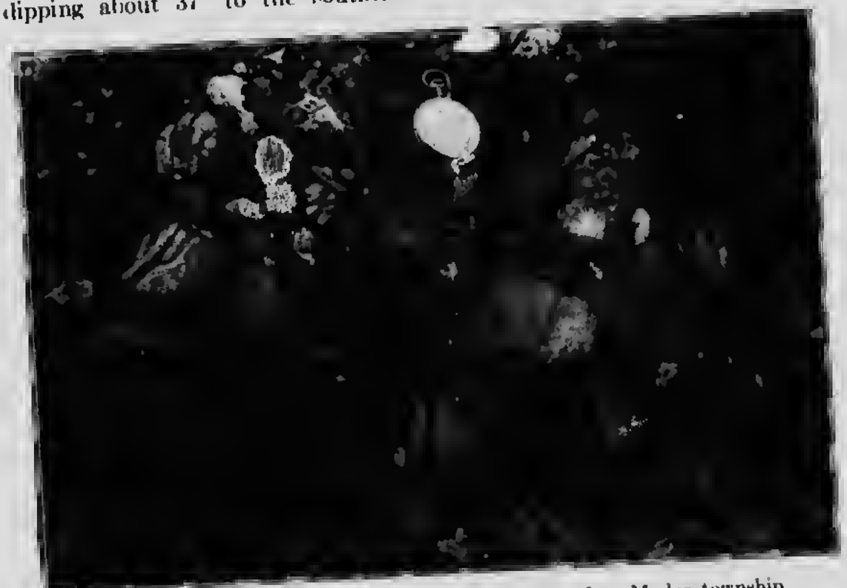


Fig. 3.—Limestone conglomerate? lot 4 concession five, Madoc township, Hastings county, southeastern Ontario.

exposed, and most of the members of the party considered that the "conglomerate" lies unconformably on the andesite.

ROCKS EXAMINED ON AUGUST 10TH.

The party left the village of Madoc in six automobiles on the morning of August 10 and travelled about 45 miles in a northeasterly direction across the counties of Hastings, Addington and Frontenac. Each member was given a geological map on a scale of one-half mile to an inch, published by the Ontario Bureau of Mines, which embraced the area traversed. The route passed over Pre-Cambrian rocks of the Keewatin, Grenville, Laurentian, Hastings and post-Hastings series, and afforded opportunities for observing these ancient rocks. The first point examined is about three and a half miles east of Madoc, at the northwest corner of lot 2 in the second concession of the township of Madoc, where an excellent exposure of schistose Hastings conglomerate occurs. The pebbles, which show considerable variety, consist in part of crystalline limestone, proving the existence of an unconformity between the crystalline limestone, which occurs in large volume a few hundred yards to the south, and the Hastings conglomerate.

The base of the Grenville series was next examined. The point where this is well exposed lies about a mile northeast of the village of Actinolite, in the township of Elzevir. There occur hornblende-schists of the Keewatin on which rest quartzites and greywackes now altered to quartz-mica-schists and resembling the Coutchiching of northwestern Ontario. The latter pass upward into crystalline limestone, the whole series of quartz-mica-schists

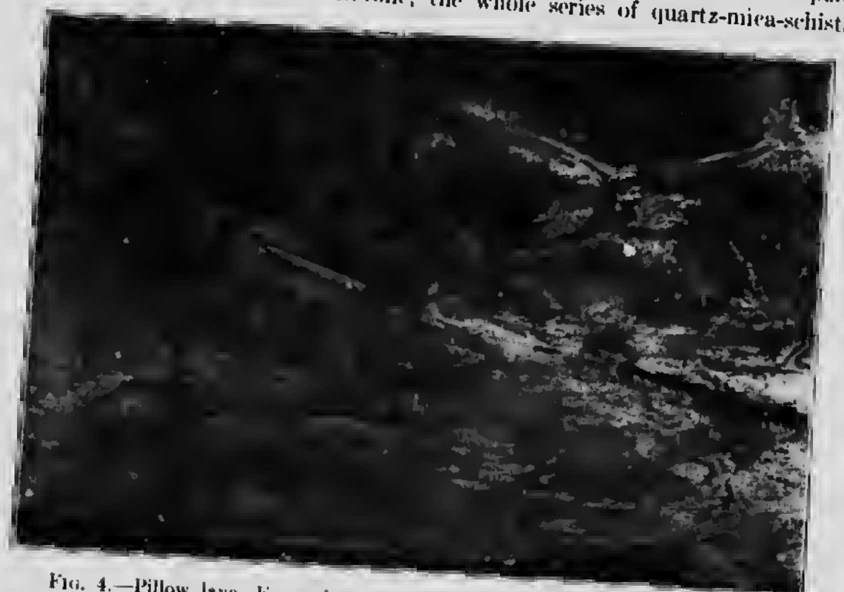


FIG. 4.—Pillow lava, Keewatin series, Barrie township, southeastern Ontario. These lavas are generally altered to amphibolites and green schists, but in this area the ellipsoidal structure is well preserved.

and limestone having a thickness, on this cross-section, of about 1,100 feet measured across the schistosity. The contact between the quartz-mica-schist and Keewatin hornblende-schists is such as to indicate that the Grenville sediments were depsoited on the surface of the Keewatin lavas without erosion of the latter.

The party then proceeded to Bishop Corners, Barrie township, Frontenac county, passing over extensive areas of Laurentian granite-gneiss, and also of Keewatin greenstones and Hastings conglomerate in less volume. About half a mile south of Bishop Corners, lot 3, Addington road, Anglesea township, in a field a few hundred yards east of the Addington road, is an excellent exposure of the Hastings conglomerate containing, among other fragments, pebbles of quartzite, banded chert, white quartz, quartz-porphyry and crystalline limestone. It was remarked by some of the members of the party that the rock resembles certain facies of the Lower Huronian conglomerate of the Lake Superior region. The base of this conglomerate may be seen resting unconformably on the Keewatin hornblende-schists less than a hundred yards west of the Addington road, where the basal member may be observed to consist largely of fragments of the adjacent Keewatin greenstone-schist.

About half a mile north of Bishop Corners, on lot 8, Addington road, Barrie township, and to the east of the Addington road a short distance, there occur low hills of pillow lavas of the Keewatin series (Fig. 4). These can be traced gradually into hornblende-schists, or amphibolites, proving conclusively the igneous origin of the green schists. The pillow lavas in which the ellipsoidal structure may be clearly recognized have an areal extent in this vicinity of two or three square miles.

After examining this outcrop the members of the party proceeded to Bon Echo Inn, Mazinaw lake, several miles to the north, where luncheon was served. They then went to the southern part of the township of Barrie to examine a contact of the Hastings conglomerate and a quartzite of the Grenville series. The nature of the contact, which is well shown on lot 24 in the first concession of the township, aroused discussion, it being held by some members that the relationship between the conglomerate and quartzite is a conformable one, while others considered that an unconformity is clearly shown by the fact that the conglomerate contains many pebbles of the quartzite.

This being the last point to be examined, the party left for Madoc, where they arrived about 8 o'clock the same evening. Toronto was reached the following morning.

CYRIL W. KNIGHT.

Excursion C 1.

TRANSCONTINENTAL VIA CANADIAN PACIFIC RAILWAY AND CANADIAN NORTHERN RAILWAY.

AUGUST 4TH—SEPTEMBER 6TH.

Leader: F. D. ADAMS.
Associate leader: J. B. TYRRELL.
Secretary: J. MCLEISH.
Assistant secretary: H. S. DE SCHMID.
Guides:

J. A. ALLAN, Calgary to Kamloops, August 20-25.
A. E. BARLOW, Coldwell, Banff to Golden, Sudbury, August 15, 20, 23, September 5.
C. H. CLAPP, Victoria, August 26-27.
W. H. COLLINS, Iron Spur to Fort Frances, August 16-17.
R. A. DALY, Banff to Vancouver, August 20-25.
C. W. DRYSDALE, Sicamous to Vancouver, August 25.
J. C. GWILLIM, Bankhead to Calgary, August 20, August 30.
W. A. JOHNSTON, Fort Frances to Winnipeg, August 17.
E. M. KINDLE, Stonewall, Stony Mountain, August 18.
A. C. LAWSON, Iron Spur to Fort Frances, August 16-17.
A. MACLEAN, Stony Mountain, Stonewall and Snake Island, August 18, September 1.
A. L. PARSONS, Kenora, Port Arthur, Loon Lake, September 2-3.
S. J. SCHOFIELD, Victoria, August 26.
W. J. SUTTON, Victoria, August 26-27.
W. L. UGLOW, Iron Spur to Fort Frances, August 16-17.
C. D. WALCOTT, Field, August 22.
R. C. WALLACE, Stony Mountain, Stonewall and Snake Island, August 18, September 1.
M. E. WILSON, Iron Spur to Fort Frances, August 16-17.

Members: Mrs. F. D. ADAMS, Canada; H. M. AMI, Canada; KARL ANDRÉE, Germany; HANS ARLT, Germany; H. G. BACKLUND, Argentine Republic; H. BÄCKSTRÖM, Sweden; Miss F. BASCOM, United States; A. BIGOT, France; KARL BODEN, Germany; L. E. DE BUGGENOMS, Belgium; H. M. CADELL, Scotland; Mme. B. CAREZ, France; L. CAREZ, France; E. C. CASE, United States; Mrs. CASE, United States; S. CERULLI-IRELLI, Italy; A. P. COLEMAN, Canada; M. F. CONNOR, Canada; J. DEPRAT, Indo-China;

C. H. DINHAM, Scotland; S. DUFAULT, Canada; Miss MARINA EWALD, United States; L. L. FERMOR, India; L. E. GENTIL, France; W. L. GOODWIN, Canada; Miss ELIZABETH GREGORY, United States; F. VON GROTE, Germany; Miss ALIDE GRUTTERINK, Netherlands; A. S. GUINSBERG, Russia; M. I. GOLDMAN, United States; C. A. HANIEL, Germany; A. HARKER, England; Miss LAURA HATCH, United States; Miss AIDA HEINE, United States; J. McD. HILLS, United States; JOHN HORNE, Scotland; W. F. HUME, Egypt; T. J. JEHU, Scotland; C. KEYES, United States; L. M. LAMBE, Canada; L. DE LAMOTHE, France; A. C. LANE, United States; Mrs. LANE, United States; H. LANTENOIS, Indo-Chine; F. LOEWINSON-LESSING, Russia; V. LOEWINSON-LESSING, Russia; P. C. LORY, France; H. F. P. LÜCK, Germany; A. MAILHIOT, Canada; E. DE MARGERIE, France; E. MATTIROLO, Italy; G. MERCIAI, Italy; L. MICHALON, France; L. MILCH, Germany; G. A. MOLENGRAAFF, Netherlands; E. S. MOORE, United States; A. M. MILLER, United States; T. C. NICHOLAS, England; L. O. PACKARD, United States; W. PAULCKE, Germany; G. H. PERKINS, United States; P. D. QUENSEL, Sweden; Mrs. QUENSEL, Sweden; H. PEYERIMHOFF, France; Miss C. A. RAISIN, England; Miss ANNA RATHGEN, Germany; W. H. RICE, United States; A. J. RIEDEL, Germany; E. ROMER, Austria; G. SAUGRAIN, France; A. SCHENCK, Germany; C. SKOTTSBERG, Sweden; T. SKOUPHOS, Greece; G. STEINMANN, Germany; P. STEPANOV, Russia; H. W. STILLE, Germany; E. STOLLEY, Germany; E. STRATANOWITZ, Russia; J. DE SZÁDECZKY, Hungary; P. M. TERMIER, France; Mlle. M. TERMIER, France; E. TIETZE, Austria; N. TILMANN, Germany; I. P. TOLMAČEV, Russia; TH. TSCHERNYCHEW, Russia; J. A. VALIQUETTE, Canada; O. WELTER, Germany; E. T. WHERRY, United States; J. WHITE, Canada; E. WIGGLESWORTH, United States; J. M. WORDIE, England; P. ZOUDE, Belgium.

In parts of the excursion, the following joined: F. FRECH, Germany; J. P. HOWLEY, Newfoundland; R. E. HORE, Canada; W. H. McNAIRN, Canada; A. ROTHPLETZ, Germany.

It was originally intended to cover the territory included in this itinerary by two separate excursions. One of these was to traverse the main line of the Canadian Pacific railway directly to Vancouver and return by the same route; the second was to cross Lakes Huron and Superior, continue westward over the Canadian Northern railway to Calgary, and thence to Vancouver via the Canadian Pacific railway, returning over both these lines.

It was found, however, that by combining them into one slightly longer excursion, a better opportunity would be afforded the participants to obtain a good general knowledge of Canadian geology between Toronto and the Pacific coast, along the main lines of the Canadian Pacific and Canadian Northern railways.

Itinerary. Westbound, the excursion followed the main line of the Canadian Pacific railway as far as Port Arthur; thence along the Canadian Northern railway to Winnipeg; and from Winnipeg to the Pacific coast along the main line of the Canadian Pacific railway. The first section of the route lay within the Pre-Cambrian complex of northern Ontario, passing through the classic districts of Rainy lake and Steeprock lake. The second section of the route traversed the plains and prairies of the interior of the continent, underlain by nearly horizontal Palæozoic, Cretaceous and Tertiary strata, the first mentioned overlapping the Pre-Cambrian to the east. The third section traversed the Cordillera and terminated at Victoria on Vancouver Island. The general structure of the cross-section of the mountain system and of the component mountain groups; the enormous thickness of strata which, in certain districts, afford continuous sections from Pre-Cambrian to Mesozoic;

FIG. 1.—*Atikokania*-bearing Pre-Cambrian limestone on Steeprock lake, Ontario.

the widespread vulcanism and attendant phenomena of the western part of the section; and the general physiography of the region were seen in a striking manner.

Eastbound, the excursion returned over the main line of the Canadian Pacific railway through the Cordillera as far as Calgary, which is situated on the plains in sight of the Rockies. From Calgary it turned northward to Edmonton. The return across the Great Plains from Edmonton to Winnipeg was made over the Canadian Northern railway, which follows a more northerly route than that followed westbound. From Winnipeg to Toronto, the excursionists travelled by the Canadian Pacific railway, visiting on the way the well-known Pre-Cambrian districts of the Lake of the Woods, Port Arthur and Loon Lake, as well as the famous nickel-copper deposits of Sudbury district.

The excursion occupied 23 days and 119 persons participated in it.

Thursday, August 14.—The special train was made up and ready for occupation at 6.30 p.m., an hour before the time set for departure from Union station, Toronto. Allotment of sleeping compartments had been made beforehand, so that although many members arrived at the last minute, there was no confusion. Shortly after leaving Toronto, each piece of baggage was in its proper place in the baggage car, in care of a baggagemaster and was readily accessible at any later time.

The train, specially prepared for this trip, left Toronto at 7.30 p.m. It consisted of two dining cars with supply car; two baggage cars, one for personal baggage and the second fitted with shelves to hold the specimen boxes supplied each member; one tourist car and five standard sleeping cars, making in all a train of eleven new cars.

Dinner was served on the train, and despite the diversity of languages, cordial relations among the members were soon established, many renewing acquaintances made at the last Congress, held in Sweden in 1910.

Friday, August 15.—All day the train traversed the southern margin of the Canadian shield—the rocky country to the north of Lake Huron and Lake Superior,—giving the party an opportunity of seeing something of the character of the surface of this foundation of the geological column in North America. At White River Dr. Barlow gave a brief address on the nepheline syenites and associated alkaline rocks which the party was to see a little later. The train then proceeded to Peninsula, where a stop of three-quarters of an hour was made to examine an exposure of these rocks a short distance west of the station. At this point Excursion C 2, which left Toronto half an hour after C 1, passed and the members of the two excursions had an opportunity of exchanging greetings.

The train then proceeded to Coldwell, letting the party off about a mile east of the station, where the alkaline intrusives form a high cliff on the south side of the railway. It was dark when the excursionists rejoined their train at Coldwell.

Saturday, August 16.—The excursion arrived at Port Arthur, at the west end of Lake Superior, during the night, and having been transferred to the line of the Canadian Northern railway, continued into Rainy River district. The first stop was made at Iron Spur to examine the Seine series and to observe the progressive metamorphism which those rocks display as the Algoman granite, which intrudes them, is approached. The geological relations were explained by Dr. Lawson and Mr. Uglow, who acted as guides in this district.

Atikokan was reached immediately after lunch. From this station the party followed a trail through the woods for 2½ miles to Steeprock lake, walking over good exposures of typical Keewatin schists. Embarking in motor boats and flat-bottomed scows towed by launches the party proceeded up the lake to view exposures of the Steeprock series, in which Dr. Lawson has recently discovered *Atikokania Lawsoni*, one of the most ancient fossils known. Specimens of this were found in comparative abundance in certain places in the face of the high limestone cliffs which rise abruptly from the waters of the lake. The relations of the Steeprock series to the adjacent batholithic granite and Keewatin volcanics were also examined at several highly interesting outcrops.

The *Atikokania* gave rise to interesting discussions among the palaeontologists of the party, some acknowledging its organic origin while others were more or less doubtful on this point. The validity of the evidence on which the Steeprock series, occupying as it does an isolated basin, had been assigned to the stratigraphical position given to it by LAWSON was also a subject of considerable discussion.

In the evening the party returned to the train, some in the launches, which followed down the course of Seine river, and others threading the mazes of the forest on foot. The train remained all night at Overflow Siding, proceeding early next morning to Banning.

Sunday, August 17. Before breakfast the party visited an interesting series of post-Glacial faults in Seine series rocks, about nine kilometres west of Banning station. The next stop was made at Mine Centre, at 8.15 a.m. Arrangements had been made there for waggons to take about 60 of the party, while the rest went by trail and canoe, to visit the unconformity between the Seine series and the Keewatin-Laurentian complex near Bad Vermilion lake.

FIG. 2.—Members of Excursion C 1 crossing Bad Vermilion lake, Ontario.

As the day was fine the greater number of the excursionists chose the path through the woods to the lake, where Indians waited to paddle them across. The basal conglomerate of the Seine series rests, in this locality, upon Laurentian granite; the granite was found to grade upward into an arkose, apparently the product of decomposition in situ, the arkose in its turn merging into the conglomerate. An interesting band of Keewatin limestone and an irruptive contact between the granite and anorthositic gabbro were also examined.

In the afternoon the excursion train proceeded to Bears Pass station. There the excursionists separated into two parties, one walking along the railway, the other going in motor-boats, to view the Coutchiching, Keewatin and Algoman rocks on Rainy lake. Both parties were enabled to trace out a great anticline of Coutchiching sediments that dip on both sides under Keewatin schists.

Monday, August 18. Winnipeg day. On rising in the morning the party found that the train had passed out of the rocky Pre-Cambrian country and was traversing a wide, level plain, the bed of the great glacial Lake Agassiz. The train reached Winnipeg at 7 a.m., and while the party was breakfasting, was transferred to the tracks of the Canadian Pacific railway.

After breakfast a special train took the party to Stony Mountain and Stonewall. At Stony Mountain, under the guidance of Messrs. WALLACE, MACLEAN and KINDLE, the great quarries of highly fossiliferous, Upper Ordovician limestone were visited. The members made large collections of fossils both there and from the Silurian strata exposed at Stonewall. From the mountain a magnificent view was obtained over the great plain of Manitoba, underlain by the sediments of Lake Agassiz.

During the remainder of the day the excursionists were the guests of the city. Special street cars first took the party to City Park, where they were entertained by the city council at luncheon. Mayor DEACON, in a few well chosen remarks, welcomed his guests at what he described as the gateway to one of the greatest wheat fields of the world. A suitable reply was made by Dr. ADAMS on behalf of the Congress, as well as by Dr. HUME, Professor TSCHERNYSCHEW, M. TERMIER and others for their respective countries. A photograph of the party was then taken on the steps of the Club. On returning to Winnipeg the party motored to the Country Club, where a pleasant hour was spent, afternoon tea being taken among the historic surroundings of old Fort Garry.

The train left Winnipeg for the West at 9 p.m.

Tuesday, August 19.—The day was spent crossing the plains and no stop was made until Medicine Hat was reached at 7 p.m. Mr. A. K. GRIMMER, Mr. A. B. WILCOX and others of the local committee met the train here, and under their guidance the whole party was taken in motor cars, kindly furnished by the citizens, to the municipal power plant and then to one of the great gas wells on the outskirts of the town, obtaining on the way an excellent view of the western plain, which at this point is deeply incised by the rapidly flowing Saskatchewan river. When all the party had assembled in the dusk of the evening the well was "blown off." The flame of burning gas, shooting up into the air for a distance of nearly a hundred feet, blazed like a gigantic torch, illuminating the whole surrounding country. The excursion proceeded westward at 9 p.m.

Wednesday, August 20.—For the past forty-eight hours the train had been travelling over the slightly rolling plains of the second and third prairie steppes, that extended as far as the eye could reach. At daybreak the members of the party obtained their first glimpse of the mountains as the train threaded its way up the valley of Bow river past Canmore and Bankhead to Banff. From Banff, which was reached at 8 a.m., the party drove first to the "Cave and Basin," where Dr. ALLAN briefly described the topographical and geological features of the district to be visited during the day. After inspecting the cave, from the basin of which the spring of sulphurous water issues, the "Upper Spring," which issues from the lower slope of Sulphur mountain was visited. Here, most of the ladies of the party, at the invitation of Mr. JAMES WHITE of the Dominion Commission of Conservation, left the main party and drove to a number of points of special beauty in that portion of Banff National Park. The other members of the party ascended Sulphur mountain, which rises to a height of 2,500 feet above the Upper Sulphur spring. The ascent occupied rather more than two hours, the winding path up the slope of Sulphur mountain displaying a very good section of the succession of Devonian, Lower Carboniferous and Upper Carboniferous strata, of which the mountain is formed.

From the summit of the mountain a wide view was obtained over the eastern portion of the Rocky Mountain range, which is here crossed by Bow river. This was one of the finest, as well as one of the most extensive of the many instructive views seen during the excursion. The succession of Devonian, Carboniferous and Permian strata, folded and overthrust on one another and on the Cretaceous, as well as a number of interesting physiographical features presented by the landscape, were pointed out and explained in a short address given by Dr. ALLAN at the top of Sulphur mountain. After a short rest the party descended, visiting on the way the falls of Spray river near the Canadian Pacific Railway hotel at Banff.

At 3 p.m. a special train took the party from Banff to Bankhead, where they were cordially received by the management of the Bankhead coal mines and were shown over the property by Mr. GUERNSEY, the manager, Mr. GWILLIM, and Mr. STERLING, Inspector of Mines for Alberta. A small party, under the guidance of Dr. ALLAN, walked to Lake Minnewanka and Cascade river and examined a splendid section that extends from the Upper Carboniferous to the Cretaceous. The members of this party obtained a number of interesting fossils. The special train left Bankhead at 6 p.m. and stopped at the outskirts of the little town of Banff to allow the party to see the herd of buffaloes kept in the Government Reserve at that place. The animals were driven out of the woods by a mounted cowboy, giving the members of the party an opportunity of seeing them to advantage and of securing photographs.

During the afternoon and evening a number of the members visited the warm sulphur baths at Banff, while Mr. LORY left on the westbound train for Laggan to make the ascent of Mt. Lefroy next day.

Thursday, August 21.—The train left Banff at 6 a.m. and between that point and Laggan, followed the valley of Bow river, on both sides of which rise majestic mountains. Laggan was reached shortly after 7 a.m., and the party at once proceeded by motor railway to Lake Louise. On the grounds in front of the Châlet, Dr. ALLAN gave a short address outlining the geology of the district, the main features of which were to be seen during the day. Leaving Lake Louise at 8.25 a.m. the party commenced the ascent to Look-Out Point, passing on the way Mirror lake and the mountain spur known as the Little Beehive. At the last named point a short halt was made to enjoy a view of Mount Lefroy and Mount Victoria, which could be seen to the south, with their glaciers and snowfields, standing out against the blue background of the sky.

From Lookout Point a very fine view was obtained of the portion of the Rocky mountains just west of the section seen the day before from the top of Sulphur mountain. The mountains seen from Lookout Point, however, are made up of Cambrian strata resting on a basement of Pre-Cambrian rocks. The long stretch of Bow River valley visible from this point could be seen following along a great, eroded anticline of Pre-Cambrian shales. These shales are especially well exposed on the lower slopes of the mountains on both sides, while the middle slopes and the summits of the mountains present one of the finest and thickest developments of the Cambrian found in any part of the world. All three divisions of the Cambrian, Lower, Middle and Upper, are here represented. The character of the mountain slopes was seen to be directly influenced by the varying character of the beds constituting the different members of the Cambrian succession. The rocks are well exposed, since here, as elsewhere throughout the Rocky Mountains, the slopes are bare and nearly free from vegetation; hence arises the name Rocky, applied to this most easterly range of the Cordilleran system. Details of the geological succession were pointed out by Dr. ALLAN, who gave an admirable address at Look-Out Point.

During the descent several brief halts were made for the purpose of collecting Cambrian fossils at several horizons. A more westerly path was selected for the return so as to skirt the end of Victoria glacier and afford a near view of its terminal moraine; continuing around the south end of Lake Louise the Châlet was reached at 1 p.m., and lunch was served.

In the afternoon the excursionsits, some driving and some on horseback, visited the Valley of the Ten Peaks, passing by the mouth of Paradise valley on the way. Both are typical, glacial, hanging valleys, and glaciers were seen at the upper end of each. Around the Valley of the Ten Peaks, as the name indicates, there rise ten gigantic mountain peaks, each of them showing the Lower and Middle Cambrian succession. Moraine lake lies in the basin between the large moraine and the Wenchemna glacier. Mount Temple, 3,543.6 metres, the highest peak in this part of the Rocky mountains, stands between these two valleys.

On returning to Lake Louise the party immediately proceeded by the motor railway to Laggan where dinner was awaiting them on the excursion train. Mr. LORY, who had left the preceding evening, rejoined the party at the Châlet, having successfully made the ascent of Mount Lefroy.

Friday, August 22.—The train left Laggan at 6 a.m. and half an hour later reached the summit of Kicking Horse pass. There a short stop was made at the Great Divide, or continental watershed, where Mount Bosworth, a great erosion block carved out of the Cambrian rocks, was in full view.

While the party was at breakfast, the train passed through the two spiral tunnels, 3,200 feet and 2,890 feet long, respectively, by which the Canadian Pacific railway has reduced the grade of its line at this point. Then, passing the Yoho valley, the Monarch lead-zinc mine, situated 1,000 feet above the railway and Mount Stephen, Field was reached at 8 a.m.

Part of the excursionists collected trilobites from the fossiliferous shales of the Middle Cambrian on the side of Mount Stephen, 2,600 feet above the railway; the others drove to the natural bridge on Kicking Horse river and on to Emerald lake.

About thirty of the men climbed Mount Stephen. Most of them returned to Field at lunch time; but some of the more enthusiastic paleontologists remained on the mountain all day. In descending Mount Stephen the only serious accident of the trip occurred. Professor COLEMAN was unfortunate enough to slip and break one of the small bones of his ankle. He was at once brought down on one of the ponies to the hotel, where the doctor set the fracture so successfully that the patient was able to continue with the party to Victoria.

FIG. 3.—Lake Louise and Victoria glacier from the garden of the Châlet, Laggan, B.C.

In the afternoon waggons and saddle horses were provided, and the whole party went to Yoho valley and Takakaw falls, situated about 11 miles from Field. The drive was a very enjoyable one; the beautiful scenery of

Yoho valley, with Takakaw falls appearing like a bridal veil on its sheer south wall, and the magnificent Alsulkan glacier closing in its head, gave the members of the party some idea of the beauties that may be found in the heart of the Rocky mountains. Field was reached again about 7 p.m.

In the evening Dr. WALCOTT, who had come from his camp on Burgess pass, where he had been collecting fossils for several weeks, gave an interesting address in the parlors of the Canadian Pacific Railway hotel. He traced the gradual development of our knowledge of the Cambrian succession in the Rocky mountains, speaking more especially with reference to the discovery of fossil-bearing horizons at various points in the range.

Saturday, August 23.—Leaving Field at 7 a.m., the train continued on its way west, short stops being made at Leanchoil and at Glenogle, where fossils were collected from a very fine exposure of black, graptolitic shales.

Golden, in the valley of Columbia river, was reached at 9.25 a.m., and the crossing of the Rocky Mountain range was completed. At this point Professor DALY explained the origin and character of the Rocky Mountain trench, through which the Columbia flows, and gave a brief outline of the geology of the Selkirk mountains, which the train was about to cross.

Leaving Golden, short stops were made at Beavermouth, Gateway and Rogers Pass, (situated on the axis of the main Selkirk syncline and the highest point in the Selkirks on the line of the Canadian Pacific railway). Glacier was reached at 1.05 p.m. After lunch the party ascended Mount Abbott to Observation Point, from which an extended view was obtained over the great Selkirk synclinorium. Thence the ascent was continued to a point about a mile farther on, where an excellent view of Mount Sir Donald and the Great or Illecillewaet glacier was obtained. This glacier was visited later in the day and very striking evidence of its retreat during recent years was observed. The train remained all night on the siding at Glacier in order that the next stage of the journey might be made during daylight, the members of the excursion thus being able to view the scenery of the Western Selkirks.

Sunday, August 24.—Leaving Glacier at 7 a.m. the train descended to the "Loop," where the Selkirk tunnel, when completed, will emerge at its western portal. Bonney glacier was seen on the left and at Illecillewaet gorge (Albert Canyon) was seen a fine series of exposures of the lower beds of the Laurie group of the Beltian system of the Selkirks, consisting of argillite with a few intercalated lenses of blackish limestone, cut by a few basic dykes.

The party then proceeded to Albert Canyon station, where the basal conformity between the Selkirk and Shuswap series was observed.

At Revelstoke, the next stopping place, the train once more reached the valley of Columbia river, having crossed the Selkirk range. From where it was last seen at Beavermouth the Columbia flows northward and passes completely around the north end of the Selkirk range, a distance of 300 kilometres; at Revelstoke it flows southward toward the great lava field of the State of Washington. The ortho-gneisses, aplites and pegmatites of the

FIG. 1.—Valley of the Ten Peaks, near Laggan, Alberta.

Shuswap terrane were examined on the slope of the mountain immediately behind Revelstoke station.

Late in the afternoon, along the railway track near Clanwilliam station, the excursionists examined the sedimentary phase of the Shuswap, consisting of para-gneisses, mica-schists and quartzites with subordinate limestone, all well exposed in rock cuts. At Sicamous Junction, which was reached at 5.40 p.m. a fine view of Shuswap lake was obtained—one of the great fiord-like lakes of the Interior plateau of British Columbia, which here succeeds the rugged Columbia range just traversed. The evening was fine, clear and very still, and a wonderful golden glow enshrouded the wide expanse of the waters of the lake, from which the hills of the plateau margin rose on every side. The party walked along the railway track in the late afternoon to inspect a good section of Sicamous limestone of the Shuswap terrane.

The train remained at Sicamous all night.

Monday, August 25.—This was a day of almost continuous railway travel. The train left Sicamous at 5.40 a.m. The first stop was made at Ducks for the purpose of seeing the contact between the dark green Nicola lavas of the Triassic series and the light gray Carboniferous (Pennsylvanian) limestone.

At Kamloops twenty minutes was spent examining a band of massive trap unconformably overlain by a series of lava flows and tuffs, with which are interstratified the fossiliferous Tranquille sandstones and shales. Dr. C. W. Drysdale joined the party at this point and acted as guide for the rest of the day.

The salient points of the geology seen along the valleys of the Thompson and Fraser rivers, which are followed by the Canadian Pacific railway as it descends to the Pacific coast, were pointed out from the train. During the afternoon a stop was made at Hell's Gate near China Bar in the Fraser River cañon. The cañon is a narrow, rock-walled gorge, where the river has cut its way through the massive granodiorites of the Coast Range batholith. The party had an opportunity here of seeing the salmon "running" up the river; thousands of fish were seen resting in the eddies and from time to time struggling up-stream through the raging waters of Hell's Gate to the next sheltering eddy.

The train, as evening fell, crossed the fertile delta of Fraser river, and at 9 p.m. arrived at Vancouver. At 11.45 p.m. the party took a special steamer for Victoria.

Tuesday, August 26.—During this and the next day the excursionists were the guests of the local committee at Victoria, of which Mr. W. F. Robertson was chairman. After breakfast on the boat, they were driven through the city and its environs, the sights including several features of geological interest. A luncheon was given at the Alexandra Club by the local committee to the members of C 1 and C 2 excursions, the latter having reached Victoria one day in advance of C 1; in the afternoon a garden party was given for the excursionists by the Lieutenant-Governor of British Columbia at his official residence, and in the evening they were entertained at dinner at the Empress Hotel.

Wednesday, August 27.—In the morning, under the guidance of Dr. C. H. Clapp, the party motored to various points of geological interest near Victoria, including the pillow lavas at Albert Head. An open air luncheon provided by the local committee was partaken at Albert Head, in a grove overlooking the Pacific. Afterwards the party left for Vancouver by special steamer. The afternoon being clear, the excursionists were able to distinguish the snow-capped peak of Mt. Baker near Seattle, over 80 miles away. As night came on and Vancouver was approached the lights of the salmon-fishing fleet off the mouth of Fraser river were visible in the moonlight, forming a scene that will be long remembered.

Thursday, August 28.—After breakfast on the boat the party took the special steamer *Bowena* and sailed up Howe sound, one of the most beautiful of the British Columbia fiords, to Britannia Beach, where a few of the party disembarked. The boat with the remainder of the party continued up to the head of the inlet, returning to Britannia Beach in time for luncheon, provided by the Britannia Mining Company. After examining specimens of the copper ore, the rocks in which it occurs and the concentrating plant, the members returned to Vancouver, where the evening was spent.

At midnight the special train left by Canadian Pacific railway on the east-bound trip. Owing to the fact that a considerable number of the members of the party left at Vancouver to join the excursions to the north, while others remained in British Columbia or went south to California, the party on the eastbound trip numbered only 58.

The following list comprises those taking the return trip:

F. D. Adams, Mrs. Adams, H. M. Ami, K. Andrée, H. Bäckström, A. Bioot, H. M. Cadell, E. C. Case, Mrs. Case, L. H. Cole, M. F. Connor, R. A. Daly, P. de Lamothe, H. S. de Schmid, C. H. Dinham, S. Dufault, L. E. Gentil, W. L. Goodwin, Miss E. Gregory, Miss A. Grutterink, M. I. Goldman, C. A. Haniel, A. Harker, Miss A. Heine, J. Horne, W. F. Hume, T. J. Jehu, C. R. Keyes, S. Kozu, L. M. Lambe, A. C. Lane, Mrs. Lane, A. Mailhiot, J. McLeish, L. Milch, A. M. Milleh, T. Nicholas, W. Paulcke, G. H. Perkins, Miss C. A. Raisin, Miss A. E. Rathgen, A. J. Riedel, P. M. Roy, M. Saugrain, S. J. Schofield, T. Skouphos, G. Steinmann, P. Stepanov, H. W. Stille, E. Stratanowitz, P. Termier, Miss M. Termier, E. Tietze, Th. Tschernyschew, J. B. Tyrrell, J. H. Valiquette, O. Welter, E. Wigglesworth.

Friday, August 29.—The whole day was spent on the train *en route* through the mountains.

Saturday, August 30.—The party arrived in Calgary early in the morning and were the guests of the city during the day.

Under the guidance of Mr. Coste and Mr. Gwillim the Tregillus Clay Products plant was visited. At these works Tertiary clays are used in the manufacture of a great variety of bricks, the kilns being fired by natural gas piped from near Medicine Hat. A number of interesting Tertiary fossils were found in the clay.

On returning to the city the party was received by members of the local committee and taken in motor cars to various points of interest. At noon a luncheon was provided by the civic authorities and the beauties and possibilities of this western country were set forth in a number of speeches by the city officials. Dr. ADAMS and Dr. HORNE made suitable replies, thanking the hosts for this kind reception.

The afternoon was spent at the races at Victoria Park.

The train left Calgary at 5 p.m. and during the night reached Edmonton, the capital of the Province of Alberta, where it was transferred to the tracks of the Canadian Northern railway.

Sunday, August 31.—The train travelled eastward all day, crossing the northern plains of Alberta and Saskatchewan.

The northern plain is more rolling in character and more thickly wooded than that along the line of the Canadian Pacific railway farther south. During the early part of the day the train passed through a country given over mainly to mixed farming and ranching, though to some extent to wheat growing. Farther east, where the soil becomes heavier, wheat fields were seen, often extending as far as the eye could reach.

No stop was made during the day except at the divisional points of the railway. In the morning, after breakfast, Mr. TYRRELL gave an interesting address in the day coach on the general geological structure of the Great Plains of western Canada and in the afternoon, an address was given by Dr. STEINMANN, who selected as his subject, "Recent discoveries in the fauna of the Cambrian."

Monday, September 1.—About 6 a.m. a short stop was made at Ashville, to examine one of the terraces of glacial Lake Agassiz. The terrace was very distinct and well marked, and was photographed by many of the party.

The train then proceeded to Dauphin, Manitoba, where a special train was waiting to take the party to the shore of Lake Winnipegosis, 55 kilometres to the north. At the lake the party crossed in a steam launch to Snake island to examine the highly fossiliferous Devonian limestones of which the island is formed. Dr. WALLACE and Mr. McLEAN acted as guides for the party. The rain which had been falling all morning ceased, and the weather cleared as Snake island was reached. A landing was made in small boats and large collections of Devonian fossils were secured by the paleontologists of the party. At noon luncheon was spread on the grass, after which the members of the excursion visited the Government Fish Hatchery. Reembarking, the party returned to Dauphin and left at 7 p.m. for Winnipeg, which was reached during the night. There the train was again transferred to the line of the Canadian Pacific railway and proceeded on its way east to Kenora.

Tuesday, September 2.—Kenora, situated at the northern end of the Lake of the Woods, was reached at 8.30 a.m. About the shores of the lake there is an excellent development of Keewatin rocks, the district being, in fact, that in which the series was originally described by LAWSON. The intrusive contact of the underlying Laurentian gneisses with the Keewatin was found well exposed at the power plant, situated on an arm of Winnipeg river flowing out of the lake at this point. Mr. PARSONS acted as guide during this and the following day. At Kenora the party was very hospitably received by Captain MACHIN, M.L.A., and a committee of the citizens of Kenora, who provided a number of steam launches on which the party was taken on a most enjoyable trip around the lake. This great sheet of water, like nearly all the lakes in the Canadian shield, contains an immense number of islands, whose shores at many points show good rock exposures. After touching at a number of places for the purpose of examining the ellipsoidal greenstones and other characteristic members of the Keewatin, the party landed at the old Ophir mine, where the mode of occurrence of the auriferous quartz veins of this district was seen and where a number of specimens of quartz containing free gold were obtained from the dump of the mine. After luncheon at Bottle bay, the party continued their tour around the lake, reaching Kenora again at 6.30 p.m. The train left for the east at 11 p.m.

Wednesday, September 3.—Port Arthur was reached at 9 a.m. and the party was received upon its arrival by the mayor of the town. The members were taken in motor cars to a number of points of interest at Current River park and to Look-Out Point, where a good view over the surrounding country and over Lake Superior was obtained. The striking influence upon the topography of the great trap sheets known as the Logan sills, which in this district are intruded into Animikie shales, was clearly seen in the outlines of the cliffs which here form the shores of Lake Superior.

Leaving Look-Out Point the party was taken to the STEWART & HEWITSON quarries on the outskirts of Port Arthur, where good exposures of the intrusive diabase were seen. Several veins holding calcite, fluorite, etc., which were once worked for native silver, were also seen cutting the trap sheet. They were found to resemble in a marked manner the veins at Cobalt and are thought by some geologists to be of the same age.

After lunch the train continued eastward to Loon Lake, where extensive exposures of the Keweenawan and Animikie with their associated iron ores were examined. At 5 p.m. the train left for Sudbury.

Thursday, September 4.—Dr. BARLOW acted as guide to the party during this and the succeeding day, which were spent in the Sudbury district.

The train first stopped at a point just east of Windy lake, where the geology of the western margin of the great nickel-bearing intrusive was studied in a railway cut. The gradual differentiation of the intrusive was well seen in this section. The party then took the train again and, while lunch was being served, crossed to the Murray mine on the eastern side of the great spoon-shaped intrusive. Here the norite, filled with nickel-bearing pyrrhotite and copper pyrite, is exposed on the bare hills and was examined at many points. The party then walked to Sudbury, reaching there at 7 p.m.

Friday, September 5.—While breakfast was being served, the train left for the Creighton mine, where an enormous body of rich ore is being worked by the Canadian Copper Company. The mine was reached at 8 a.m. and the party was escorted through it by the officials of the company. No. 3 mine, owned by the same company, was then visited and an hour was spent there in making a study of the relation of the ore to the norite in which it occurs. Luncheon was served while the party was on the way to No. 2 mine, which was next examined.

At 1.30 p.m. the party divided, one group under the leadership of Dr. BARLOW making a hurried examination of the local geology of the district around Copper Cliff, while the other, in charge of several of the officers of the company, paid a visit to the smelter and the extensive works of the Canadian Copper Company at Copper Cliff.

Returning to Sudbury the train immediately proceeded to Coniston, seven miles to the east, where the smelter and works of the Mond Nickel Company were visited under the guidance of Mr. CORLISS, the general manager of the company, and some of the officers of his staff.

On the way back to Sudbury some members of the party stopped at Ramsay lake, to examine the Huronian conglomerate in that vicinity. Sudbury was reached at 7 p.m., where the party found dinner awaiting them. As this was the last meal before the close of the excursion, Mr. TERMIER on behalf of the excursionists, in a few well chosen words conveyed to Dr. ADAMS the thanks of the party and told him how much everyone had appreciated the excursion and the admirable way he and his assistants had carried it through. Dr. ADAMS and Mr. McLEISH replied on behalf of the Congress and Mr. SNELL on behalf of the Canadian Pacific railway.

Saturday, September 6.—The train reached Toronto sharp on time at 7 a.m. and Excursion C 1 was thus brought to a close, having been *en route* for 23 days, during which time it had gone 6,000 miles.

L. H. COLE.

Excursion C 2.

Transcontinental, via Canadian Pacific, Grand Trunk Pacific, Temiskaming and Northern Ontario, and Grand Trunk railways.

Leaders: R. W. Brock, J. McEvoy.

Guides: J. A. Allan, A. G. Burrows, C. Camsell, C. H. Clapp, W. H. Collins, H. C. Cooke, W. J. Dick, D. B. Dowling, C. W. Drysdale, O. S. Finnie, J. C. Gwillim, O. E. LeRoy, G. G. S. Lindsey, A. MacLean, W. F. Robertson, B. Rose, S. J. Schofield, J. S. Stewart, J. T. Stirling, W. J. Sutton, A. W. G. Wilson.

Secretary: H. E. T. Haultain.

Assistant Secretary: H. Fréchette.

Members: E. M. Anderson, Scotland; John Ashworth, England; Sir Augustine Baker, Ireland; H. E. Boeke, Germany; O. B. Bøggild, Denmark; L. H. Borgström, Finland; A. H. Brooks, U.S.A.; E. W. Byrde, England; C. T. Cartwright, Canada; J. Charronnier, Canada; A. A. Cole, Canada; J. Cummings, Canada; L. E. T. Dahlblom, Sweden; W. J. Dick, Canada; R. G. Drinnan, Canada; Rev. P. Dupaigne, Canada; G. L. Dunn, Scotland; B. E. Fernow, Canada; Mrs. Fernow, Canada; O. S. Finnie, Canada; S. McL. Gardner, Scotland; P. Gleis, U.S.A.; B. Gürich, Germany; Mrs. H. E. T. Haultain, Canada; H. M. Hausen, Russia; Bernard Hobson, England; T. C. Hopkins, U.S.A.; R. E. Hore, Canada; F. R. Van Horn, U.S.A.; J. P. Howley, Newfoundland; P. F. Hubrecht, Netherlands India; Mark Hurll, Scotland; J. McG. Hurll, Scotland; K. Inouye, Japan; H. G. Ives, U.S.A.; J. T. B. Ives, U.S.A.; G. Jarvis, Canada; J. Keele, Canada; D. E. Keeley, Canada; C. Kido, Manchuria; G. Kennedy, Canada; P. Kukuk, Germany; H. M. uttman-Johnson, England; C. Lebling, U.S.A.; E. Maier, ali; S. G. Martius, Germany; J. G. McMillan, Canada; J. cEvoy, Canada; Mrs. McEvoy, Canada; B. McNeill, England; Mrs. McNeill, England; D. S. McIntosh, Canada; E. T. Mellor, South Africa; B. L. Miller, U.S.A.; J. Morel, Belgium; R. B. Murray, England; J. L. Parker, Canada; F. B. Peck, U.S.A.; Mrs. Peck, U.S.A.; S. Powers, U.S.A.; W. R. Rogers, Canada; Mrs. Rogers, Canada; G. Saugrain, France; J. Shaw, Canada; J. T. Singewald, U.S.A.; C. Spruyt, Belgium; T. de Surzycki, Russia; B. L. Thorne, Canada; F. T. Thwaites, U.S.A.; J. B. Tyrrell, Canada; H. B. Wallis, England; A. G. B. Wilbraham, England; T. F. W. Wolff, Germany; B. Weigand, Germany; M. E. Wilson, Canada; C. W. Wright, Italy; Mrs. Wright, Italy; R. Zuber, Austria.

The Honourable Louis Coderre, Federal Minister of Mines, and his party, consisting of Madame Coderre, Madame Falardeau, Miss Coderre, Masters Louis and Charles Coderre, and Mr. E. Paradis accompanied the excursion on the government car Roleen.

Excursion C 2 afforded an opportunity to the members to see the general geological features of Canada between Toronto and the Pacific coast and to obtain more particular information regarding the coal-fields and metalliferous ore-deposits of central and western Canada, that occur along the route.

The principal coal mines visited were those situated near the Canadian Pacific railway; at Hillcrest, Blairmore and Coleman in Alberta and at Corbin and Fernie in British Columbia; those at Nanaimo on Vancouver Island; and those at Edmonton, Tofield and Pocahontas on the Grand Trunk Pacific railway. The principal metal mines examined included the copper-gold-silver deposits of Phoenix and the gold-copper mines at Rossland, in British Columbia; and the nickel-copper mines at Sudbury, the silver mines at Cobalt and the gold mines at Porcupine, in Ontario.

Westbound, the excursion travelled over the Canadian Pacific railway from Toronto to Vancouver by way of the Crowsnest Pass and the Arrow lakes, and from Vancouver by steamer to Victoria. The return was made over the Canadian Pacific railway to Edmonton, whence a trip was made over the new Grand Trunk Pacific railway to Tête Jaune Pass, and by the last named railway from Edmonton to Fort William. The Canadian Pacific railway was followed from Fort William to North Bay, from which point a side trip was made by the Temiskaming and Northern Ontario railway to Porcupine. Toronto was reached by the Grand Trunk railway from North Bay.

From Toronto to Vancouver and back to Edmonton and from Fort William to Toronto on the eastbound trip, the excursionists travelled in a Canadian Pacific special train. A Grand Trunk special was chartered for the portion of the trip made over that railway.

The excursion left Toronto on the evening of August 14, and no stop was made until Winnipeg was reached on the 16th. At Winnipeg the members were entertained at luncheon by the city; a welcome to the prairie region was extended by the civic officials, to which suitable responses were made by the Hon. Mr. Coderre and others of the visitors. Afterwards, a number of the excursionists took a special train to Stony Mountain and Stonewall to examine the Ordovician and Silurian sections exposed there.

At Medicine Hat, which was reached on the evening of the 17th, the excursionists were taken in motor cars to see one of the gas wells and to examine other features of interest in and near the city.

The 18th and 19th were spent in an examination of the coal formations and mines along and adjacent to the Crowsnest Pass railway line; Hillcrest, Blairmore and Coleman were visited on the first day and Corbin and Fernie on the second.

At Hillcrest a study was made of effects of the great Turtle Mountain land-slide of 1903. Standing at the edge of the fan of detritus brought down by the slide, Mr. BROCK described to the assembled members the structural geology of the region and its causative connection with the disaster.

Part of the members visited the eastern side of the synclinal valley and were able to see at the Bellevue mine the folding to which the Kootenay formation has been subjected. Others traversed the western side of the valley and visited the Hillcrest mine where the folding and faulting of the Kootenay were well displayed.

At Blairmore the coal mines and the quarries in the Fernie shales (Jurassic) were visited by the geologists while the ladies of the party were taken for a drive to the top of Blairmore mountain.

The coal mines of the International Coal Company at Coleman provided another point of interest and the members who were interested were taken on an inspection trip underground for a distance of about two miles. The rest of the party meanwhile walked up the valley for three miles to see the complete section exposed there of the Lower Cretaceous area and to view Crowsnest mountain, a thrust block of Devono-Carboniferous overlying the Cretaceous. In the evening, the Crowsnest Pass coal operators and officials entertained the excursionists at dinner, at Frank.

Through the courtesy of the British Columbia and Eastern railway the special train was conveyed from MacGillivray to Corbin, about sixteen miles to the south and situated on an eastern outlier of the Crowsnest coal-field. The members had an opportunity, there, to examine the plant and mines of the Corbin Collieries. The whole party were taken by official train to a point 1,000 feet above the valley to see the remarkable coal deposit 130 feet thick which is being mined there by steam shovel.

At Fernie the excursionists were very heartily welcomed and were taken by special train to the mines at Coal Creek where the geological structure of the district and the methods pursued in mining were explained by Mr. W. R. WILSON and Mr. JAS. MCEVOY. The opportunity was seized by some of the party during a walk back to Fernie to collect some of the fossils which are fairly abundant in the Jurassic beds of the region. In the evening the members were the guests of the town at a smoking concert.

The greater part of the 20th was taken up in the traverse of the Purcell range between the Columbia-Kootenay valley and Kootenay lake. The steamer *Nasookin* transferred the members across Kootenay lake from Kootenay Landing to Nelson, while the special train was taken across in barges. At Nelson the party visited the rooms of the Board of Trade where they inspected a collection of the ores and minerals of the Kootenay district. An informal reception was held afterwards at the Strathcona Hotel, at which the members met many of the mining men of the district.

Nelson was left early in the morning of the 21st by special train for Phoenix, the Hon. Mr. CODERRE and party remaining over for the day at Nelson and rejoining the party at Castlegar. A stop was made at Grand Forks, where the city provided motor cars for a short run around the city and to the smelter of the Granby Consolidated Mining, Smelting & Power Company. At Phoenix, the copper-gold-silver deposits, which occur in a zone of contact metamorphism, as illustrated by the Granby mine, were examined. A late luncheon was given by the officials of the Granby Company, and was followed by a brief trip underground from No. 3 tunnel to the 400-foot level. The pillar and room method is used in mining these low-grade ore deposits and from the dimensions of the stopes the visitors were able to gain a good idea of the size and form of the ore bodies. The train then went on to Greenwood, where, in the evening, an hour was spent by a few of the members in a visit to the British Columbia Company's smelter, under the guidance of the general manager.

In the early morning of the 22nd, the train arrived at Castlegar and the members transferred to a special day train for Rossland. Arriving there, a visit was made to the Trail smelter and lead refinery. After a luncheon tendered by the mine operators at Rossland, the afternoon was given up to geological excursions, both on the surface and underground.

The excursionists were divided into two parties; the underground party studied the ore deposits, their structural relations to the various rock formations and the very intricate dyke and fault systems and collected specimens of the country rocks and of the ore and gangue minerals; the surface party examined the outcrops of the Centre Star and LeRoi veins and the associated rocks, the "White dyke" and a section of the Palæozoic and Mesozoic formations along the Great Northern railway near the O. K. mine. They had an opportunity also to study the local physiography. Tea was served at the Rossland club by the ladies of Rossland and a dinner was given in the evening by the city, followed by a reception at the Club. The members left by special boat train for Robson where they embarked on the steamer *Bonnington* which had been specially chartered for the Arrow Lakes trip.

The 23rd was spent on the steamer in traversing the Arrow lakes, the daylight trip through the basin portion of the lakes affording excellent views of the various features of a typical Cordilleran lake. An hour's stop was made at Halcyon where a visit was made to one of the few hot-springs occurring in the Canadian Cordillera. The special train was boarded again at Arrowhead and, with the exception of an hour's stop at Revelstoke, the journey was continued without interruption to Kamloops.

On the 24th the members were the guests of the city of Kamloops and a boat trip was taken on Kamloops lake and Thompson river from Kamloops to Savona. Several stops were made *en route* to examine the section of Tertiary lavas and sediments.

At Tranquille the members were enabled to see a 4,800-foot section of Lower Miocene volcanic rocks, of both flow and fragmental types; they examined the Battle Bluff gabbro intrusion and the rocks of the Nicola group; and had an opportunity, as well, of collecting fossil fish from the Miocene lake beds at Red Point. At Copper Creek they were shown a mercury mine, and examined the Coldwater group conglomerate (Oligocene). They made a study also of the local physiography.

Vancouver was reached early on the 25th, and the members left on the morning boat for Victoria. The afternoon was spent in examinations of the interesting geological features in the vicinity of Victoria while a few members took advantage of the opportunity to make a side excursion to the coal fields of Nanaimo.

On the 26th, C 1 and C 2 excursions met in Victoria and the united excursionists devoted the morning to geological trips to neighbouring points of interest. A luncheon was given by the Provincial government in honour of the visitors, at the Alexandra club; and in the afternoon a most enjoyable garden party was held by Lieutenant Governor Patterson and Mrs. Patterson at Government House. The two excursions then separated, the members of C 2 returning by the night boat to Vancouver.

At Vancouver, motors were provided by the mayor and city council and the forenoon of the 27th was spent in viewing the city. The train left at noon on the return trip to Toronto, permitting the members to enjoy a daylight run through the lower part of the Fraser Cañon. A short stop was made in the cañon to see the salmon-run at Hell's Gate rapids.

On the 28th the portion of the Selkirks between Glacier and Banff was traversed by daylight. A brief stop was made at Lake Louise and two hours of the evening were spent at the Canadian Pacific Railway hotel at Banff.

At Edmonton, which was reached on the morning of the 29th, an interesting programme was provided by the city, including a boat trip down the Saskatchewan river and an examination of the coal measures of the Edmonton formation exposed in the river banks opposite the city. In the afternoon a luncheon was tendered to the excursionists at the Empire Hotel, and in the evening they transferred to a Grand Trunk Pacific special train and left for Tête Jaune, which lies 300 miles to the west of Edmonton, within the Rocky mountains.

The 30th was spent in a daylight traverse of the Rockies from Hinton to Tête Jaune. On the way, the coal-measures at Pocahontas were examined and, the weather conditions being extremely favourable, a magnificent view of Mount Robson was enjoyed from the passing train. Mount Robson is one of the great peaks of the west side of the axial range and it is here that the wonderful section of Cambrian and pre-Cambrian sediments 16,000 feet in thickness occurs. The return trip from Tête Jaune was commenced in the late afternoon.

On the 31st a part of the morning was spent in an examination of the lignite coal deposit at Tofield and in the afternoon a stop of a couple of hours was made at Wainwright to see the herds of bison and wapiti in the National Park.

Saskatoon was reached on September 1, and the members were taken for a motor drive around the city under the auspices of the Board of Trade. The eastbound trip was resumed at noon and continued without any stops of note to Fort William, which was reached on the evening of the 2nd. The members were immediately transferred to the Canadian Pacific Railway special train which was in waiting and the trip was continued through the Pre-Cambrian country to the north and north east of Lake Superior, to North Bay. The capabilities of the excursionists as entertainers was proved on the evening of the 3rd, when a most enjoyable impromptu concert programme was carried out in the dining car. From North Bay a side trip was made to the silver and gold districts of Cobalt and Porcupine.

Porcupine was reached at noon of the 4th, and the Dome and Hollinger gold mines were visited.

At Cobalt, which was reached on the 5th, the morning was devoted to a surface geological trip and in the afternoon several of the silver mines were visited.

The special train left for Toronto in the early morning. A farewell meeting of the excursionists and the railway officials who had accompanied them, was held in the dining car before the train arrived at North Bay, and many of the members took advantage of the occasion to express their appreciation of the arrangements made and their thorough enjoyment of the trip.

At North Bay one of the cars was detached from the special and sent on to Sudbury with eighteen members who had expressed a wish to see the nickel-copper deposits at that place.

On Saturday, September 6th, the main excursion arrived in Toronto in the early morning. The Sudbury contingent visited the Murray mine where they were entertained by the officials of the Dominion Nickel Company. In the afternoon they visited the smelter at Copper Cliff, and No. 3 mine of the Canadian Copper Company, returning to Sudbury for dinner. They left Sudbury that evening, reaching Toronto on the morning of the 7th.

O. E. LeRoy.

Excursion C 6.

SUDBURY—COBALT—PORCUPINE.

AUGUST 15TH– 24TH.

This excursion covered practically the same ground as Excursion A 3. The leaders and guides were the same as for Excursion A 3 except that Dr. WALKER was in charge at Sudbury and Mr. P. E. HOPKINS acted as secretary in place of Mr. W. R. ROGERS.

Members: W. S. BAYLEY, U.S.A.; RICHARD BECK, Germany; MAX BELOWSKY, Germany; ALFRED BERGEAT, Germany; HERBERT BOWMAN, England; W. H. BUCHER, U.S.A.; A. G. BURROWS, Canada; JEAN CAILLEBOTTE, France; J. M. CLARK, Canada; COLLIER COBB, U.S.A.; A. A. COLE, Canada; J. A. DRESSER, Canada; E. DUPUY DE LÔME, Spain; D. A. DUNLAP, Canada; Mrs. DUNLAP, Canada; H. V. ELLSWORTH, Canada; W. H. EMMONS, U.S.A.; J. W. EVANS, England; PAUL R. FANNING, Phillippine Islands; A. FURLAND, Canada; STEINAR FOSLIE, Norway; P. GEIJER, Sweden; A. GRIMALDI, Italy; C. HENROTIN, Canada; T. HIKI, Japan; Sir THOS. HOLLAND, England; R. J. HOLDEN, Canada; E. HOWE, U.S.A.; B. JAEGER, England; C. W. KNIGHT, Canada; J. P. KRUSCH, Germany; R. LACHMANN, Germany; HENRY LEIGHTON, U.S.A.; A. G. LEONARD, U.S.A.; MARK LUBOSCHINSKY, Russia; A. MARIN, Spain; WILLET G. MILLER, Canada; H. E. MITSCHERLICH, Germany; C. A. O'CONNELL, Canada; Mrs. O'CONNELL, Canada; A. L. PARSONS, Canada; G. M. PAHT, England; P. PRUVOST, France; T. W. READ, U.S.A.; R. P. ROGERS, Canada; Mrs. ROGERS, Canada; H. SAINT-CLIVIER, France; J. W. SAMOJLOFF, Russia; E. R. SCHOCH, South Africa; J. J. SEDERHOLM, Russia; W. E. SEGSWORTH, Canada; SYDNEY SMITH, Canada; Mrs. SMITH, Canada; PIERJE SOUSTCHINSKY, Russia; W. VERNADSKY, Russia; J. E. WOODMAN, U.S.A.; PAUL WEISS, France.

During this excursion a little longer time was spent at Cobalt than on A 3, a full day being given to the geology of Lake Timiskaming. Another full day, after leaving Porcupine, was given to the Alexo nickel mine and to the Kirkland lake gold area, which had become more accessible, through the building of a wagon road since the visit of members of Excursion A 3.

At Cobalt the members of the Cobalt Branch of the Canadian Mining Institute held a reception in honour of the excursionists, and at Kirkland lake Mr. and Mrs. CHAS. A. O'CONNELL entertained at dinner.

W. G. MILLER.

Excursions C 8 and C 9.

C 8. PACIFIC COAST: VANCOUVER TO MALASPINA, SKAGWAY, DAWSON AND RETURN.

AUGUST 28TH—OCTOBER 4TH.

C 9. SKEENA RIVER VALLEY: PRINCE RUPERT TO MORRICETOWN.

AUGUST 28TH—SEPTEMBER 1ST.

Leader: R. G. McCONNELL.
Guides: R. W. BROCK, W. F. ROBERTSON, D. D. CAIRNES, and L. MARTIN (for Alaska).
Secretary of C 8: W. A. JOHNSON.
Secretary of C 9: G. G. AITKEN.
Members: Sir AUGUSTINE BAKER, Ireland; L. E. DE BUGGENOMS, Belgium; H. M. CADELL, Scotland; Mrs. D. D. CAIRNES, Canada; L. CAREZ, France; Mme. CAREZ, France; J. CHARBONNIER, Canada; A. P. COLEMAN, Canada; J. DEPRAT, Indo China; L. L. FERMOR, India; Mrs. FERMOR, India; G. GÜRICH, Germany; Miss LAURA HATCH, U.S.A.; T. McD. HILLS, U.S.A.; H. M. HAUSEN, Finland; K. INOUYE, Japan; C. KIDO, Manchuria; H. F. P. LÜCK, Germany; H. M. LUTTMAN-JOHNSON, England; E. MAIER, Chili; E. DE MARGERIE, France; S. G. MARTIUS, Germany; E. S. MOORE, U.S.A.; JEAN MOREL, Belgium; R. B. MURRAY, England; H. DE PEYERIMHOFF, France; Miss ANNA RATHGEN, Germany; W. H. RICE, U.S.A.; E. ROMER, Austria; A. SCHENCK, Germany; C. SPRUYT, Belgium; E. STOLLEY, Germany; R. S. G. STOKES, U.S.A.; F. T. THWAITES, U.S.A.; A. G. B. WILBRAHAM, England; F. R. VAN HORN, U.S.A.; B. WEIGAND, Germany; A. W. G. WILSON, Canada; T. F. W. WOLFF, Germany; J. M. WORDIE, England; L. G. ZOUDE, Belgium.

The members of both excursions left Vancouver for Prince Rupert by the specially chartered C.P.R. steamer *Princess Maquinna*, Captain McLEOD, master, on August 28 at 8 p.m.

The usual steamer route, sheltered from Pacific storms except at two points by the succession of long islands flanking the mainland coast, was followed to Prince Rupert. A stop was made at Alert bay to enable the members to examine the Kwakiutl Indian village with its numerous totem poles. With this exception the journey was continuous and occupied 38 hours, Prince Rupert being reached at 10 a.m., August 30. The Coast range, with its heavily glaciated surfaces and the numerous, deep, steep-sided, winding fiords cutting back into it and separating the fringing islands from each other and from the mainland, formed the principal subjects of discussion during the voyage. Typical hanging valleys join the fiords in places but are much less numerous than ordinary graded valleys; and general opinion inclined to the view that they could not be due to a general deepening of the fiord troughs by ice erosion, and that, in some instances at least they may be simply extended cirques.

EXCURSION C 9.

At Prince Rupert the members taking C 9 excursion up the Skeena valley by the Grand Trunk Pacific railway left the steamer immediately on docking and boarded a waiting train, which left at once.

Leader: R. G. McCONNELL.
Guides: W. F. ROBERTSON and D. D. CAIRNES.
Secretary: G. G. AITKEN.
Members: Sir AUGUSTINE BAKER, L. E. DE BUGGEONMS, L. CAREZ, Mme. CAREZ, J. CHARBONNIER, A. P. COLEMAN, J. DEPRAT, G. GÜRICH, K. INOUYE, CHUTARO KIDO, E. DE MARGERIE, JEAN MOREL, A. SCHENCK, R. S G. STOKES, B. WEIGAND, TH. F. WOLFF, P. ZOUDE.

Excursion C 9 interested the members both from a geological and a geographical standpoint, as the ground covered embraced both the rugged Coast range and a wide section of the strongly contrasting, rough and little known interior district of northern British Columbia, with its groups of high, pinnacled peaks separated by wide, terraced valleys. The picturesque group of the "Seven Sisters," fringed on the north with hanging glaciers, was especially admired.

Two days, August 30 and 31, were alloted to the excursion but, owing to the late hour at which the boat reached Prince Rupert, only a portion of the first day was available. This was occupied in making the run of 212 miles to the end of steel near Morricetown. Only two stops were made, one at Kitsalas cañon and the other at Skeena crossing. At the latter point Skeena river is sunk in a deep trough, and strongly contorted Jurassic beds are well displayed along the cañon walls.

The train was billed to leave on the return journey at 8 a.m. but the members were astir long before this and, under the leadership of Mr. ROBERTSON, walked two miles to examine the wild Morricetown cañon, cut by Bulkley river through a thick andesite sheet domed into an anticline. Salmon-fishing by the Indians at the cañon added interest to the visit.

During the return trip from Morricetown to Prince Rupert short stops were made at a number of interesting geological and scenic points. At mile 198 the Skeena formation, of Lower Cretaceous age, is well exposed in a long cut. Some of the beds are fossiliferous, and collections of fossil plants were made. At Mile 194 a thick band of coarse, greyish tuffs and volcanic breccias, cut by nearly contemporaneous andesitic dykes, was examined. This band is included in the Hazelton formation, of Upper Jurassic age. The ordinary rocks of this formation consists of dark feldspathic sandstone and shales, interbanded with occasional andesitic sheets. They are exposed in numerous cuttings along the railway track westward to Mile 124, and stops were made at two points to examine them. Specimens of the epidotized volcanic rocks of the Kitsalas formation were collected at Kitsalas cañon and in passing through the Coast range collections were made of the normal batholithic granodiorites, the basic schists included in them and the pegmatitic and other dykes cutting them. The last stop of the trip was made at mile 16, at a section of the Prince Rupert schists west of, but near, the western edge of the Coast Range batholith, where interesting contact effects of the batholith on the bordering sedimentary rocks were examined.

Prince Rupert was reached at 7.30 p.m. and at 10 p.m. the *Princess Maquinna* returned from Granby bay and the excursionists going north went on board. The following members of the excursion returned to Vancouver by S.S. *Prince George*. G. G. AITKEN, L. CAREZ, Mme. CAREZ, J. CHARBONNIER, J. DEPRAT, W. F. ROBERTSON, R. S. G. STOKES.

Trip to Granby bay.

The members of C 8 excursion not taking excursion C 9 up the Skeena, spent the day in Prince Rupert as the guests of the City and the Board of Trade. The programme included a motor-boat trip to see the harbour, the new city water-works, cold-storage plant and dry-dock and a motor-car trip about the city. The Prince Rupert club extended its privileges to the members. At 10 p.m. the party sailed for Granby bay on the *Princess Maquinna*, under the leadership of Mr. R. W. BROCK. Anyox, the new town of the Granby Consolidated Mining Smelting and Power Company, was reached at 8 a.m. on August 31 and the party were met by Mr. O. B. SMITH, Mr. W. A. WILLIAMS, and other officers of the company. A train specially prepared for their convenience conveyed the party to the mine. The new railway cuts afforded opportunities to see the rock formation, and from the train a good view was obtained of the dense coast vegetation. After spending several hours examining the surface geology and ore outcrops and studying the underground geology of the large copper-ore bodies, the party again entrained, and were taken through the smelting and power plants, in course of construction, after which they returned to Anyox. The company's fine new hotel was formally opened by a luncheon provided to the excursionists by the company. The very pleasant and instructive visit to this new mining camp was then brought to a close, the afternoon being spent in sailing down Observatory Inlet and Portland Canal. After a stop of a few minutes at Port Simpson, the *Princess Maquinna* returned to Prince Rupert to pick up the members who had accompanied Excursion C 9.

Continuation of C 8 Excursion.

The *Princess Maquinna* left Prince Rupert for Juneau at 11 p.m. August 31. Mr. N. F. OGILVIE of the Boundary Survey joined the excursion at Prince Rupert and acted as extra guide on the Alaskan trip. The daylight run on September 1, from Ketchican northwards up the coast through intricate passages and narrow canals, was particularly enjoyable. The day was unusually clear and the gorgeous panorama of rocky heights, snow and ice-fields, which opens out in the Coast range after passing Wrangel narrows, was seen to full advantage.

The steamer stopped at Douglass, Alaska, at 9 a.m., September 2, a visit to the Treadwell mine near that point being included in the programme. The excursionists were met at the wharf by President BRADLEY and general manager KINZIE, of the Alaska-Treadwell Gold Mining Company, and taken to the mine on tram-cars. They were afforded all facilities for examining the underground workings and huge stopes in the wide, crushed and silicified diorite dyke which forms the ore-body of this celebrated mine, and were shown the various processes used in the treatment of the ore.

A delay of some hours at Juneau, to replenish the supply of oil fuel, interfered somewhat with the programme, as the *Maquinna* left that port too late to traverse Icy strait (filled with bergs from Glacier bay) before dark and was obliged to lie over. The passage was safely made early on the following morning and the run continued up the exposed portion of the coast extending from Cross sound to Yakutat bay. The day was comparatively clear and magnificent views were obtained of the great glaciers and giant peaks of the Fairweather range.

The night of the 3rd was spent in DeMonti bay near the mouth of Yakutat bay and on the 4th the steamer proceeded up Yakutat bay and its continuation, Disenchantment bay, to the mouth of Russel fiord. These waters are still practically uncharted, and near the head of Disenchantment bay, immediately opposite the great tidal ice cliffs of Hubbard glacier, the steamer grounded on a reef, at a point where the few soundings shown on the chart indicated 140 feet of water. Fortunately she was proceeding slowly at the time and the rising tide soon floated her off. As, apparently, the ship had not been seriously injured, the captain continued the run up Russell fiord and anchored for the night at Seal cove opposite the snout of Hidden glacier. On the 5th Hidden glacier was examined in the forenoon and Nunatak glacier, at the head of Nunatak fiord, in the afternoon. The recent history of both glaciers was explained by Mr. LAWRENCE MARTIN, whose familiarity with the region made him a most efficient guide. Numerous small but definite and unmistakable fault scarps in the schistose rocks bordering the Nunatak glacier were attributed by Mr. MARTIN to shattering by severe earthquakes in 1899. Changes in elevation in the whole region bordering Yakutat bay and Russell fiord and probably extending over the whole St. Elias range, occurred at the same time. These changes, mostly of uplift but some of depression, are clearly indicated by raised beaches and sunken areas along the coast.

Variegated glacier was visited on the morning of the 6th and at noon a landing was made on Haenke island in Disenchantment bay to examine a raised beach stated to have been suddenly elevated in 1899 to a height of 18 feet 6 inches above highwater mark. The absence of ordinary vegetation and the presence of unbroken sea shells still clinging to the rocks afforded ample proof of the recency of the uplift.

The trip down Yakutat bay proved a memorable one. The clouds which had hidden the higher peaks on the way up lifted and the whole central St. Elias range from St. Elias in the west, soaring high above the wide Malaspina ice-plain at its base, to snow-clad Logan, gleaming white in the distance and Cook rearing itself high above Disenchantment bay, stood revealed in all its glorious beauty. Members of the excursion familiar with the Himalayas, Andes and other great mountain ranges expressed the opinion that in scenic splendour the view of the St. Elias alps with their towering snow streaked mountains and huge ice streams descending to the sea, was probably unsurpassed anywhere in the world.

Owing to the delay caused by the grounding of the steamer, the time allotted to the excursion did not permit a landing on Malaspina glacier and a night run was made down the coast to Cross sound. On the 6th Muir and other glaciers at the head of Glacier bay were examined and evidences of recent retreats and advances on a large scale were pointed out by Mr. Martin. The Grand Pacific glacier, east of Muir glacier, which in 1912 retreated up Reid inlet across the International Boundary into Canadian territory, was subsequently found by Mr. Martin to have again advanced and closed up for the time being that potential Canadian port.

The *Princess Maquinna* sailed for Skagway on the 7th and reached that port the same evening. Mr. Martin, Mr. Thwaites and Dr. Romer remained in Glacier bay to continue glacial investigations there, while the main party, 37 in number, left the steamer on the morning of the 8th and took the regular White Pass and Yukon train to Whitehorse, *en route* to Dawson. Stops were made at a couple of points to examine the Coast Range rocks and at Lewis lake to see an old lake basin partially drained during the construction of the railway. Dr. Thompson, M.P., joined the excursion at Bennet, having come up from Dawson for the purpose of welcoming the members to the territory, and assisted in drawing up a programme and in other ways.

At Whitehorse the party took the river steamer *Selkirk*, which was waiting there, and proceeded at once down Lewis river. The water was at a good stage and the journey down the Lewis to the Yukon and down the Yukon to Dawson was made without mishap or delay. A short stop was made at Tantalus to examine some coal seams in the Jura-Cretaceous, now being mined there. Fossil plants were also collected at the same point.

The *Selkirk* reached Dawson at 3.30 p.m. on the 10th. The members of the excursion were met at the wharf by Mr. Black, Commissioner of Yukon Territory and others and welcomed to the city. As time was limited, what was left of the afternoon was utilized in visiting one of the great dredges belonging to the Boyle Concessions, Limited, operating on the Klondike flats. Mr. JOSEPH Boyle accompanied the party to the dredge, conducted them over it and lucidly explained the various workings. In the evening the members were entertained by Mr. Commissioner BLACK at Government House.

It was decided to spend the two days alloted to the Klondike visit in a general review of the camp, although this necessarily left little time for detailed examinations of interesting points. An early start was made on the 11th in motors and horse vehicles, two kindly furnished and driven by the owners, Mr. THOMAS of the Yukon Gold Company and Mr. BOYLE of Boyle Concessions, Limited, and the rest supplied by the Territorial Government. Mr. BLACK, the present commissioner and Mr. CONGDON, a former one, both old timers in the district and familiar with its history, accompanied the party and proved good guides.

The route taken was up Klondike river to the mouth of Hunker creek, then up Hunker creek and the long hill at its head to the Hunker-Dominion divide, and down Dominion creek to Granville, returning to Dawson by Sulphur and Bonanza creeks, a total distance of 108 miles. On the way out stops were made in the forenoon at the mouth of Bear creek, the headquarters of the Boyle Concessions, Limited, where the members were shown the various types of gold obtained in dredging, and at Goldbottom and other points along Hunker creek. The Dome road-house, on the summit, was reached at noon, and the members lunched there as guests of the Territorial Government. An excellent view of the rugged Ogilvie range is obtained from this point. In the afternoon, on the way down Dominion creek, the members had an opportunity of seeing individual mining on one of the few claims not owned or controlled by large companies.

Dominion creek differs from Hunker and Bonanza creeks in the absence of a secondary valley and in the wide flats which bottom its lower portion. Its present valley bottom, as the guides explained, corresponds to the flats on which the high-level White Channel gravels of Hunker and Bonanza creeks rest. It is less accessible from Dawson than the Klondike creeks, and mining on a large scale has only commenced. The Granville Mining Company, controlled by Mr. A. N. C. TREADGOLD, is at present engaged at several points in the preparatory work of removing the muck overlying the frozen gravels. This is done partly by ground sluicing and partly by hydraulicking, and the members had an opportunity at Granville of seeing these methods employed. When the muck is removed over a sufficient area, and the gravels exposed to the sun and atmosphere, they thaw out slowly and can be dredged.

While at Granville the members of the excursion were entertained at dinner and breakfast by the Granville Mining Company; and the sincere thanks of the excursionists are due to Mr. DOLAN, Mr. BRADENBURG, Mr. RENDALL and other officials of this company for the trouble they took in entertaining and finding accommodation for their numerous guests and also for assistance in transportation.

The return journey to Dawson on the 12th was made in a steady rain and the programme for the day could not be fully carried out. Ascending the Dome ridge, the rain changed to snow and the extended view of the Yukon peneplain, obtainable from the summit on a clear day, was obscured. Grand Forks, at the junction of Eldorado and Bonanza creeks, was reached by the motors at 1 p.m. and by the horse-drawn vehicles about two hours later. An excellent lunch at this point kindly provided by the Territorial Government was greatly appreciated after the long drive. In the afternoon the members were taken to see a "clean up" on King Solomon hill by the Yukon Gold Company, the result of several weeks hydraulicking. An hydraulic plant working on the White Channel gravel was also in operation and the various processes in the recovery of the gold were explained by Mr. COFFEE of the Yukon Gold Company.

The return drive was delayed by the heavy roads and some of the vehicles did not reach Dawson until long after dark. The members, after dinner at the "Regina," immediately boarded the steamer *Whitehorse* which was billed to leave for Whitehorse at 11 p.m. The long up-run journey from Dawson to Whitehorse occupied nearly five days. The members were, however, greatly interested in the bed-rock and glacial geology and in the physiography of the Yukon and Lewis valleys, and the tedium of the protracted trip was relieved by animated discussions on these subjects. Stops were made at Selkirk to examine the basal sheet exposed at that point and below Rink rapids to collect specimens of white volcanic ash. This wind-blown, recent deposit is conspicuous in numerous sections all along the Lewis and excites the curiosity of all travellers. The exact point from which the material was derived is not yet known; it was probably somewhere in the vicinity of Mount Natazhat in the St. Elias range.

The excursion reached Whitehorse on the evening of the 17th, early enough to allow the members to visit Whitehorse rapids on Lewis river famous in the annals of the gold rush of '98 from the numerous accidents they occasioned. The night was spent on the boat and in the morning an early start was made for the Pueblo mine, the only mine now working in the vicinity. The ore-body of this mine is an irregular hematite mass, carrying about 3 per cent. of copper and is a typical, contact-metamorphic deposit, formed near the contact of limestone and quartz-diorite. Interesting collections of primary and secondary ore minerals and of contact-metamorphic minerals were obtained. Mr. GREENOUGH, the general manager, showed the members over the workings and had refreshments served to them before leaving.

On the way back from the Pueblo mine a short stop was made at the Best Chance ore-body, a large magnetite mass carrying a small percentage of copper. From the Best Chance the excursion train returned to the main line of the White Pass railway and proceeded directly to Skagway without further special stops. Accommodation for the members had been secured on the C.P.R. S.S. *Princess Sophia*, which sailed the same evening for Vancouver and reached that port on September 22.

At Vancouver the excursion split up into several sections. Sir Augustine Baker, G. Gürich, H. M. Hansen, H. P. Lück, E. Maier and E. Stolley returned directly to Toronto. The other members, with the exception of L. de Buggenoms, C. Kido, Th. F. W. Wolff and C. Spruyt, who remained behind, separated into two divisions, one party in charge of Mr. McConnell returning east by the main line of the C.P.R., and the other under the leadership of Mr. Brock, by the Crowsnest Pass line.

Those returning by the main line were: A. P. Coleman, F. R. Van Horn, K. Inouye, S. Martius, H. M. Lüttman-Johnson, J. Morel, B. Weigand, A. G. B. Wilbraham and F. T. Thwaites.

Stops were made in the mountains at Glacier, Laggan and Banff and, in addition, three of the party, Morel, Van Horn and Weigand, spent some time at Field and made large collections of trilobites and other fossils from the well-known trilobite quarry on Mount Stephen. At Banff the principal excursion was to the top of Sulphur mountain. The repeated over-thrust faulting characteristic of the eastern Rockies is well seen from this point.

The excursion left Banff on September 27 for Sudbury by the regular afternoon train. A special sleeping car for the use of the members was attached to the train at Calgary. At Medicine Hat the Crowsnest Pass party was picked up and both divisions travelled through to Sudbury together without further stops.

The Crowsnest Pass party, in charge of Mr. Brock, consisted of those members of Excursion C 8 who had come west over the main line of the Canadian Pacific railway and wished to return by the alternative route. The members were H. M. Cadell, Miss L. Hatch, L. L. Fermor, Mrs. Fermor, W. A. Johnson, T. McD. Hills, L. Martin, E. de Margerie, H. de Peyerimhoff, Miss A. Rathgen, W. H. Rice, E. Romer, A. Schenck, J. M. Wordie, and P. Zoude. They left Vancouver on the 25th by a later train than the first division. At Revelstoke they turned off the main line of the C.P.R. and proceeded down the Arrow lakes to West Robson. Here the party divided, those who had to make boat connections proceeding directly east with Mr. Johnson in charge. They were met at Nelson by Mr. D. B. Dowling, who acted as guide over the Crowsnest Pass line. The main party proceeded to Rossland. The morning of September 25 was spent in Rossland, one section of the party studying the physiography and bed rock geology with Mr. Brock, the other under Mr. Drysdale's guidance, studying the underground workings of the mines. After lunch the party motored to Trail and were shown over the smelter and refinery by Mr R. H. Stewart, General Manager of the Consolidated Mining & Smelting Company, Mr. S. T. Blaylock, assistant general manager and other officials of the company, after which they was entertained at supper by Mrs. Stewart. After this very enjoyable function the party entrained for the east. The following evening a stop was made at Frank, the night being spent at the sanatorium. Here Mr. Dowling joined the party. Next morning one section of the party accompanied Mr. Brock to the summit of

Turtle mountain, while a second was shown the landslide and the geological structure in the valley by Mr. DOWLING. At noon the party left Frank, joining the main line section at Medicine Hat that evening.

The excursion reached Sudbury at 8 a.m. September 1, and were met there by Dr. T. L. WALKER, who had come up from Toronto to act as guide. He was assisted by Mr. E. T. CORKILL of the Canadian Copper Company, Dr. COLEMAN and Mr. COLLINS. In the morning a traverse across the district was made in motors and the main features of its geology pointed out. Afterwards the members were shown through the large smelter of the Canadian Copper Company by Mr. CORKILL. Lunch at the Engineers' Club, kindly provided by the Canadian Copper Company, followed. In the afternoon the Creighton, Murray Hill and other mines were examined and the relationship of the magmatic nickel-bearing ores to the norite and rocks intruded by it was explained.

In the evening Dr. COLEMAN, Dr. WALKER, Mr. DOWLING, Mr. CADELL, Dr. VAN HORN, Dr. RIES, Mr. WORDIE, Mr. WILBRAHAM and Dr. MARTIUS returned to Toronto; Dr. ROMER had returned the preceding evening. The remaining members of the party, Mr. McCONNELL, Mr. LUTTMAN-JOHNSON, Dr. FERMOR, Mrs. FERMOR, Miss RATHGEN, Mr. INOUYE, Mr. MOREL, Dr. SCHENCK, Dr. WEIGAND and Mr. ZOUDE, spent the night at Sudbury and in the morning left for North Bay en route to the Porcupine-Cobalt camps. Mr. A. G. BURROWS of the Ontario Bureau of Mines met the excursion at North Bay, and he with Mr. ARTHUR COLE, who joined at New Liskeard, acted as official guides.

At North Bay the party took the regular train for Timmins and arrived there late on the evening of October 1. Next day the Hollinger mine and the surface outcrops of the gold-bearing veins were examined in the forenoon and in the afternoon the excursionists drove over to South Porcupine and were shown over the workings of the Dome Mining Company.

On the 3rd the party returned to Cobalt and had time in the afternoon to examine hurriedly the interesting surface geology of the camp under the guidance of Mr. BURROWS. On the 4th, the last working day of the long excursion, the members had an opportunity in the forenoon of seeing the mine workings and mill of the Coniagas Mining Company. They were kindly allowed to collect specimens of the high-grade silver ores characteristic of the camp and were entertained to lunch by the company. In the afternoon some time was spent in the Nipissing high-grade mill and a visit was made to a spectacular silver outcrop at the Crown Reserve mine. In the evening the party entrained for Toronto and reached that city, the terminal point of the excursion, on schedule time the following morning.

R. G. McCONNELL.
R. W. BROCK.

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