REGALIS · SOCIETAS · CANADENSIS

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MÉMOIRES

ET

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DE

LA SOCIÉTÉ ROYALE

DU

CANADA

TROISIÈME SÉRIE—TOME XVI

SÉANCE DE MAI 1922

EN VENTE CHEZ
J. HOPE ET FILS, OTTAWA; LA CO. COPP-CLARK (Limitée), TORONTO
BERNARD QUARITCH, LONDRES, ANGLETERRE
1922

PROCEEDINGS

AND

TRANSACTIONS

OF

THE ROYAL SOCIETY

OF

CANADA

THIRD SERIES—VOLUME XVI

MEETING OF MAY, 1922

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BERNARD QUARITCH, LONDON, ENGLAND
1922

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THE ROYAL SOCIETY OF CANADA

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1916—Fraser, C. McLean, M.A., Ph.D., Biological Station, *Nanaimo, B.C.*
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1916—Hunter, Andrew, M.A., B.Sc., M.B., Ch.B., Edin., University of Toronto, *Toronto.*
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1921—Saunders, C. E., B.A., Ph.D., Dominion Cerealist, Experimental Farm, *Ottawa.*
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Salone, Émile, professeur d'histoire au Lycée Condorcet, 68 rue Jouffray, *Paris.*
Hanotaux, Gabriel, de l'Académie française, 21 rue Cassette, *Paris.*
Lamy, Étienne, sécrétaire perpétuel de l'Académie française, 3 place d'Iéna, *Paris.*
Lorin, Henri, professeur d'histoire coloniale à l'Université de Bordeaux, 23 quai des Chartons, *Bordeaux.*

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Metzler, W. H., Ph.D., F.R.S., Edin., Syracuse University, *Syracuse,* N.*Y.*
Thomson, Sir Joseph J., O.M., F.R.S., *Cambridge, England.*

Section IV

White, Charles David, B.Sc., United States Geological Survey, *Washington, D.C.*

Section V

Osborn, Dr. Henry Fairfield, Columbia University, *New York, N.Y.*

LIST OF PRESIDENTS

1882-1883........................Sir J. W. Dawson
1883-1884........................L'honorable P.-J.-O. Chauveau
1884-1885........................Dr. T. Sterry Hunt
1885-1886........................Sir Daniel Wilson
1886-1887........................Monsignor Hamel
1887-1888........................Dr. G. Lawson
1888-1889........................Sir Sandford Fleming, K.C.M.G.
1889-1890........................L'abbe Casgrain
1890-1891........................Very Rev. Principal Grant
1891-1892........................L'abbe Laflamme
1892-1893........................Sir J. C. Bourinot, K.C.M.G.
1893-1894........................Dr. G. M. Dawson, C.M.G.
1894-1895........................Sir J. Macpherson LeMoine
1895-1896........................Dr. A. R. C. Selwyn, C.M.G.
1896-1897........................Most Rev. Archbishop O'Brien
1897-1898........................L'honorable F.-G. Marchand
1898-1899........................T. C. Keefer, C.M.G.
1899-1900........................Rev. William Clark, D.C.L.
1900-1901........................L. Fréchette, C.M.G., LL.D.
1901-1902........................James Loudon, LL.D.
1902-1903........................Sir J. A. Grant, M.D., K.C.M.G.
1903-1904........................Col. G. T. Denison, B.C.L.
1904-1905........................Benjamin Sulte, LL.D.
1905-1906........................Dr. Alex. Johnson
1906-1907........................Dr. William Saunders, C.M.G.
1907-1908........................Dr, S. E. Dawson, C.M.G.
1908-1909........................Dr. J.-Edmond Roy
1909-1910........................Rev. Geo. Bryce, LL.D.
1910-1911........................R. Ramsay Wright, M.A., B.Sc.
1911-1912........................W. F. King, LL.D., C.M.G.
1912-1913........................W. Dawson LeSueur, B.A., LL.D.
1913-1914........................Frank D. Adams, Ph.D., F.R.S., F.G.S.
1914-1915........................Sir Adolphe-B. Routhier
1915-1916........................Alfred Baker, M.A., LL.D.
1916-1917........................A. B. Macallum, Ph.D., F.R.S.
1917-1918........................W. D. Lighthall, M.A., B.C.L., F.R.S.L.
1918-1919........................Hon. Rodolphe Lemieux, LL.D.
1919-1920........................R. F. Ruttan, M.D., C.M., D.Sc.
1920-1921........................A. P. Coleman, M.A., Ph.D., F.R.S.
1921-1922........................Duncan Campbell Scott, Litt.D.
1922-1923........................J. Playfair McMurrich, M.A., Ph.D.

LIST OF ASSOCIATED SOCIETIES

Ontario

Hamilton Association for the Promotion of Science, Literature and Art.
The Hamilton Scientific Society.
L'Institut canadien-français d'Ottawa.
The Women's Wentworth Historical Society.
The Entomological Society of Ontario.
Women's Canadian Historical Society of Ottawa.
Elgin Historical and Scientific Institute.
Women's Auxiliary of the Elgin Historical and Scientific Institute.
Ontario Historical Society.
The Huron Institute.
Niagara Historical Society.
The Ottawa Field Naturalists' Club.
Royal Astronomical Society of Canada.
Canadian Institute, Toronto.
Historical Society, Kingston.
Toronto Astronomical Society.
Lundy's Lane Historical Society.
Women's Canadian Historical Society of Toronto.
United Empire Loyalists' Association of Canada.
Peterborough Historical Society.
Canadian Forestry Association.
Hamilton Ladies' College Alumnæ.
Club littéraire canadien-français d'Ottawa.
Waterloo Historical Society.

Quebec

Société du Parler français au Canada, Québec.
Société de Géographie de Québec.
Société d'Economie sociale et politique de Québec.
The Quebec Society for the Protection of Plants from Insects and Fungus Diseases.
The Antiquarian and Numismatic Society of Montreal.
L'Institut canadien de Québec.
Natural History Society of Montreal.
Microscopical Society, Montreal.
Société historique de Montréal.
Cercle littéraire et musical de Montréal.
Literary and Historical Society, Quebec.

British Columbia

The Natural History Society of British Columbia.
Academy of Science, Vancouver, B.C.

Nova Scotia

The Nova Scotia Historical Society.
The Nova Scotian Institute of Science.

Manitoba

Manitoba Historical and Scientific Society.

New Brunswick

New Brunswick Historical Society.
New Brunswick Loyalists' Society.
Miramichi Natural History Association.
Natural History Society of New Brunswick.

THE ROYAL SOCIETY OF CANADA

PROCEEDINGS FOR 1922

FORTY-FIRST GENERAL MEETING

SESSION I.—(*Wednesday, May 17*)

The Royal Society of Canada held its forty-first annual meeting in the Victoria Memorial Museum, Ottawa, on May 17, 18 and 19.

The President, Dr. Duncan C. Scott, took the chair at 10 a.m. and, having called the meeting to order, requested the Honorary Secretary to call the roll.

The following Fellows answered to their names or arrived later during the session.

OFFICERS OF THE SOCIETY

President..................Dr. Duncan C. Scott

Vice-President..............Dr. J. P. McMurrich

Honorary Treasurer.........Mr. C. M. Barbeau

Honorary Librarian.........Dr. D. B. Dowling

SECTION I.—Barbeau, C. M.; Chartier, Emile; Caron, Ivanhoe; Chapais, T.; David, Hon. L.-O.; DeCelles, A. D.; Fauteaux, A.; Gérin, Leon; Lemieux, Rodolphe; Magnan, C. J.; Mignault, P. B.; Pelletier, Georges; Perrault, A.; Roy, Camille; Roy, Pierre-Georges.

SECTION II.—Brett, G. S.; Bryce, George; Burpee, L. J.; Coyne, J. H.; Currelly, C. T.; Cruikshank, E. A.; Doughty, A. G.; Fox, W. S.; Gibbon, J. M.; Hill-Tout, Charles; Howay, F. W.; King, W. L. MacKenzie; Lighthall, W. D.; MacIver, R. M.; Macphail, Sir Andrew; Macnaughton, John; Mavor, James; Murray, Walter; Oliver, E. H.; Scott, D. C.; Shortt, Adam; Skelton, O. D.; Stewart, H. L.; Wrong, Geo. M.

SECTION III.—Allan, F. B.; Allen, Frank; Archibald, E. H.; Bain, J. W.; Boswell, M. C.; Boyle, R. W.; Bronson, H. L.; Buchanan, D.; Clark, A. L.; DeLury, A. T.; Eve, A. S.; Fields, J. C.; Glashan, J. C.; Gray, J. A.; Harkness, J.; Herdt, L. A.; Hughes, A. Ll.; Johnson, F. M. G.; King, L. V.; Maass, O.; MacKenzie, A. S.; Parker, M.A .; Patterson, J.; Plaskett, J. S.; Ruttan, R. F.; Shutt, F. T.; Stupart, Sir R. F.; Sullivan, C. T.

SECTION IV.—Adams, Frank D.; Camsell, Charles; Coleman, A. P.; Collins, W. H.; Dowling, D. B.; Dresser, J. A.; Faribault, E. R.; Johnston, W. A.; Kindle, E. M.; Knight, C. W.; McConnell, R. G.; McInnes, W.; Parks, W. A.; Walker, T. L.; Wallace, R. C.; White, James; Young, G. A.

SECTION V.—Buller, A. H. R.; Cameron, A. T.; Faull, J. H.; Fraser, C. McLean; Gibson, Arthur; Harding, V. J.; Harrison, F. C.; Huard, V. A.; Hunter, Andrew; Huntsman, A. G.; Knight, A. P.; Lewis, F. J.; Lloyd, Francis E.; Macallum, A. B.; Mackay, A. H.; Macleod, J. J. R.; McKibben, P. S.; McMurrich, J. P.; Miller, James; Moore, C. L.; Prince, E. E.; Saunders, C. E.; Thompson, W. P.; Thomson, R. B.; Willey, A.

Letters of regret for absence were received from the following: Ami, H. M.; Auclair, E. J.; Burgess, T. J.; Chouinard, H. J. J. B.; Delâge, C. F.; Emard, Mgr. Jos.-Médard; Fitzgerald, J. G.; Gosselin, Mgr. Amédée; Harris, D. Fraser; Matthew, G. F.; Morin, Victor; Montpetit, Edouard; Massicotte, E. Z.; Miller, F. R.; Prud'homme, L. A.; Paquet, Mgr. L. A.; Raymond, W. O.; Riddell, Hon. W. R.; Rouillard, E.; Schofield, S. J.; Sulte, Benj.; Scott, H. A.; Tait, John; Tyrrell, J. B.; Tory, H. M.; Walker, Sir Edmund.

It was moved by Professor Hill-Tout, seconded by Dr. Coyne, that the minutes of the annual meeting of last year as contained in the printed proceedings of last year in the hands of the Fellows be confirmed. Carried.

The Annual Report of Council, printed copies of which had been delivered to the Fellows, was then presented by the Honorary Secretary. The Report was as follows:—

REPORT OF COUNCIL

FOR THE YEAR 1921-1922

To the Fellows of The Royal Society of Canada,

The Council have the honour to present the following report on the work of the Society during the past year:—

The last Annual Meeting was held in Ottawa on May 18, 19 and 20. The meeting was a very successful one. In the previous year Council had the pleasure of reporting the largest attendance in the history of the Society but at this meeting the record was again broken, the registered attendance being one hundred. The meetings were held in the Victoria Memorial Museum and the Presidential Address and Popular Lecture were delivered in the Auditorium of the Museum. The accommodation was very satisfactory and the Council have availed themselves of the privilege again this year.

I—Proceedings and Transactions of the Society

Volume XV, Third Series of the Transactions was this year printed by the University Press, Toronto, and the copies have been distributed. The volume consists of 634 pages. The reduction in the size of the volume and in the charges for printing has resulted in a marked decrease in the cost of production, as will be seen by reference to the Honorary Treasurer's statement. In view of the reduction this year it is thought that the Sections might consider publishing a larger number of papers in the next issue.

II—Election of New Fellows

This year there were vacancies in all the Sections. The Council have much pleasure in reporting that the following candidates received a majority of the votes case and their election is submitted for confirmation.

Section I

Mgr. Joseph Médard Emard, Th.D., J.C.D.
C. J. Magnan, M.A.

Section II

W. S. Fox, Ph.D.
J. M. Gibbon, B.A.
Edward Sapir, Ph.D.

Section III

J. A. Gray, D.Sc.
A. Ll. Hughes, B.A., D.Sc.
Otto Maass, M.Sc., Ph.D.

Section IV

John A. Allan, M.A., Ph.D.
W. A. Johnston, M.A., B.Sc.
S. J. Schofield, Ph.D., F.G.S.A.

Section V

Arthur Gibson, F.E.S., F.E.S.A.
V. J. Harding, D.Sc.
F. R. Miller, M.A., M.D.
James Miller, M.D., D.Sc., F.R.C.P.E.
Charles H. O'Donoghue, D.Sc., F.Z.S.
John Tait, M.D., D.Sc., F.R.S.E.

III—Deceased Members

This year Council have to record two vacancies caused by death in the ranks of the Fellows: Dr. Ernest Myrand and the Hon. Justice Longley. Biographical sketches of these two Fellows have been prepared by Hon. Thomas Chapais and Dr. H. L. Stewart, respectively. In addition there appears in this report a biographical sketch of the late John Macoun, M.A., F.L.S., one of the Charter Members of the Society, who died on July 18th, 1920, and of whose life a sketch did not appear at the time. This biography has been prepared by Dr. A. H. MacKay, Halifax, N.S.

ERNEST MYRAND

M. Ernest Myrand, bibliothécaire de la législature provinciale, à Québec, décédé le 31 mai 1921, était l'un des membres les plus dévoués et les plus assidus de la Société royale.

Né dans la capitale du Bas-Canada, en 1854, il avait fait d'excellentes études au Séminaire de cette ville et à l'Université Laval. Après avoir terminé son cours, comme beaucoup de nos jeunes hommes de talent, il entra dans le journalisme. Il fut attaché pendant quelque temps à la rédaction du *Canadien*, dont le directeur était alors M. Tarte, publiciste belliqueux avant de devenir le politicien hardi qui fit tant de bruit dans les luttes parlementaires à Ottawa, de 1891 à 1903. M. Myrand ne s'attarda guère au labeur de la presse. Les études littéraires et historiques avaient pour lui plus d'attraits. Il put y consacrer des loisirs moins limités lorsqu'il obtint au palais de justice de Québec un emploi qu'il occupa pendant plusieurs années. En 1902 il fut nommé aux fonctions de régistraire au Secrétariat provincial. Enfin, le 31 décembre 1912, il succéda au docteur N.-E. Dionne comme bibliothécaire de la législature.

M. Myrand accomplit toujours ses devoirs de fonctionnaire avec la plus rigoureuse exactitude. Mais, entrainé de longue date au travail intellectuel, il sut trouver le temps de poursuivre sans relâche des recherches et des études qui lui ont valu une réputation méritée. La première œuvre qu'il livra au public fut une sorte d'évocation où la fantaisie et l'histoire s'alliaient dans un récit et des tableaux pleins d'un charme étrange et captivant. Elle était intitulée *Une fête de Noël sous Jacques-Cartier* et fut publiée en 1888. Ce livre eut un grand succès et classa du coup l'auteur parmi nos meilleurs écrivains. M. Myrand y faisait preuve d'une érudition très sûre et d'un talent narratif et descriptif vraiment remarquables.

En 1893 il publiait un autre ouvrage: *Sir William Phipps devant Québec.* C'est sutrout une collection de documents sur le siège subi par la capitale de la Nouvelle-France en 1690. Outre les pièces colligées et reproduites, ce volume contient des discussions critiques et des notes intéressantes pour le chercheur qui veut étudier spécialement cet évènement historique.

Dans *Monsieur de la Colombière, orateur,* M. Myrand nous initie aux anxiétés et aux allégresses patriotiques des habitants de Québec et de toute la colonie française lorsque le destruction de l'armada commandée par l'amiral Sir Howenden Walker fit échouer, en 1711, la formidable invasion qui menaçait notre pays.

Avec ses *Noëls anciens de la Nouvelle-France,* M. Myrand eut la bonne fortune d'exploiter une veine nouvelle, riche en souvenirs et en émouvantes réminiscences. Cet ouvrage est l'un des plus attachants qu'il nous ait laissés. L'auteur nous révèle l'origine, parfois profane, de la musique à laquelle de pieux personnages ont adapté des paroles qui, dans leur simplicité naïve, font désormais partie de notre tradition populaire, et qui nous sont douces et sacrées parce que nous les avons d'abord entendues sur les lèvres de nos mères, et sous les voûtes des vieilles églises où notre enfance connut le mystérieux enchantement des premières messes de minuit. Comme la *Fête de Noël,* les *Noëls anciens* ont eu les honneurs de plusieurs rééditions.

Au cours de ses études sur le siège de Québec en 1690, M. Myrand avait rencontré la haute et impressionnante physionomie du comte de Frontenac. Et, du même coup, il avait entrevu de loin la figure attrayante de la comtesse absente, l'une des "dernières" amies de la princesse de Montpensier, cousine de Louis XIV. Après plusieurs années il y revint et s'en éprit avec une ferveur qui rappelle un peu la flamme dont Victor Cousin brûla naguère pour les femmes illustres du dix-septième siècle. C'est de cette tendance rétrospective, d'ailleurs tout à fait dans l'ordre parce qu'elle était à base d'érudition, que naquit le livre intitulé *Frontenac et ses amis.* Il y a là des pages pleines de verve, où l'auteur malmène rudement quelques-uns des écrivains et des mémorialistes qui ont manqué d'égards pour sa dame.

Nous nous en voudrions d'oublier dans cette rapide nomenclature les dialogues écrits par M. Myrand pour les scènes historiques, les "pageants," représentés durant les fêtes grandioses du troisième centenaire de Québec. Il y a là surtout une chanson délicieuse cornée aux oreilles de l'envoyé de Phipps par les gamins québecquois d'il y a trois siècles. Elle est pleine de saveur et de spirituelle impertinence.

Dans toutes les œuvres dues à la plume de M. Myrand, ce qui frappe principalement c'est la manifestation simultanée de l'imagination la plus riche, la plus exubérante, et le souci de la plus minutieuse exactitude. La *Fête de Noël sous Jacques-Cartier*, qui reste son œuvre capitale, nous en offre un exemple hereux. Ce rêve, où l'on voit apparaître un mort, l'abbé Laverdière, professeur d'histoire, s'offrant inopinément comme cicérone à l'auteur, vous fait assister à des scènes imaginaires sans doute, mais où les détails de la reconstitution historique sont d'une réalité inattaquable.

Notre collègue défunt est mort en pleine activité intellectuelle. Huit jours à peine avant de succomber à la maladie qui le minait, il assistait à la session annuelle de note Société et présidait, malgré son épuisement manifeste, les séances de la Section première, dont les suffrages l'avaient choisi, en 1920, pour remplir cette fonction honorable. Il laisse à ses amis et à ses confrères l'exemple de toute une vie de labeur et de fidélité au devoir.

JAMES WILBERFORCE LONGLEY

James Wilberforce Longley, Justice of the Supreme Court of Nova Scotia from 1905 to 1922, was born at Paradise, N.S., on 4th January, 1849. He was educated at Acadia University, where he graduated in 1871, was admitted to the Bar in 1875, and took his seat in the Provincial Legislature as Member for Annapolis in 1882. In 1884 he became a member of the Government, and he held the office of Attorney-General for Nova Scotia from 1886 to 1905, resigning this position when elevated to the Supreme Court Bench.

Mr. Justice Longley's career was varied and notable. Some years before his death he suffered a paralytic stroke and—though he made a very remarkable recovery—there was an obvious failing in those powers and qualities by which in earlier life he had been distinguished. Those who knew him only in advanced age were thus

James Wilberforce Longley

unable to appreciate what he had been in his prime. It was widely recognized that he had on the Bench few superiors in weighing the value of evidence or estimating the credibility of witnesses. His activities, too, extended far beyond the field of his professional work. He was a public speaker of rare gifts, whose services on the platform were in constant request, not only in his own Province, but in many a direction outside its boundaries. His contributions to journalism were copious and effective. He took a keen interest in Canadian history, and was himself the author of two interesting biographies: *The Life of Joseph Howe* and *The Life of Sir Charles Tupper*. Other and more elaborate historical projects had been undertaken and were partially carried out when the break-down in his health prevented their further prosecution. In nothing else during his later years did Mr. Justice Longley take a deeper delight than in the work of The Royal Society, to which he was elected in 1898 and of which he was Vice-President in 1916. He never missed an annual meeting, or failed to take his part in the discussions of Section II. He was of Irish descent, a past president of the Charitable Irish Society of Halifax, and to the last was much concerned about Irish questions. By a pathetic coincidence, his death occurred on 17th March, the national Irish anniversary in celebration of which it was his invariable custom to share. In his passing from us The Royal Society has lost a Fellow who, in enthusiasm and affection for our brotherhood of letters, was surpassed by no other within our ranks.

JOHN MACOUN

John Macoun, M.A., F.L.S., one of the charter members of The Royal Society of Canada, and since 1887 Assistant Director and Naturalist of the Geogolical Survey of Canada, died in his ninetieth year at Sidney, Vancouver Island, B.C., on the 18th July. 1920, with a distinguished record of scientific exploration and public utility.

He was born at Maralin, in the North of Ireland, 17th April, 1831, emigrated at nineteen years of age with the rest of the family to settle on farm land in Seymour Township, Northumberland County, Ontario. At 28 years of age we find him attending the Normal School in Toronto; after which he became a public school teacher in Belleville, rapidly rising in the profession and in reputation as a Natural History authority until at the age of 43 we find him Professor of Botany and Geology in Albert College.

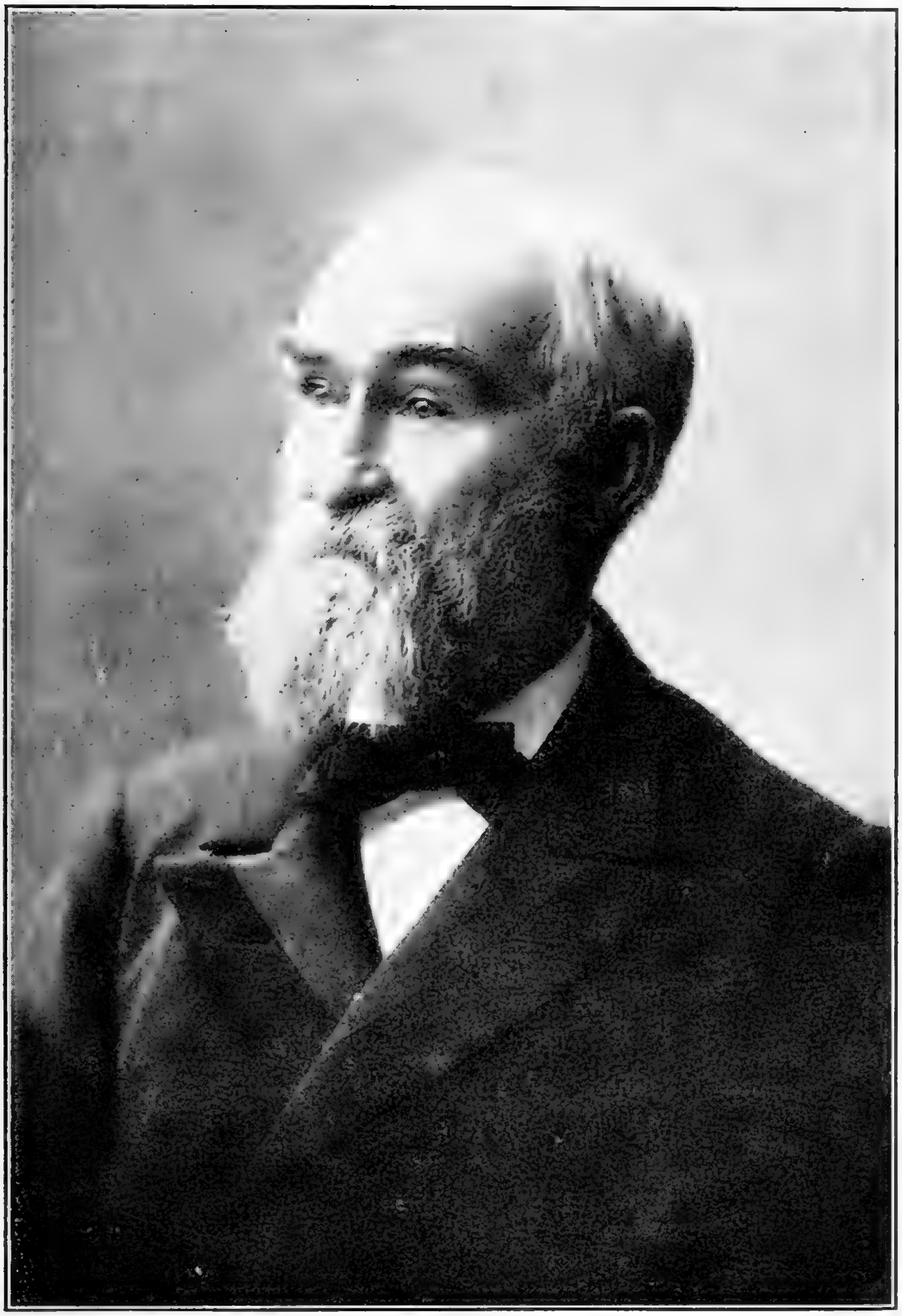
Just two years before this appointment, in 1872, we have many glimpses of him at 41 as the enthusiastic and competent botanist of the Sanford Fleming Expedition across the continent, so graphically described in the late Principal G. M. Grant's "From Ocean to Ocean."

In 1875 he was botanist to an expedition of the Geological Survey which explored the Peace River country and the adjacent Rocky Mountains. From 1879 to 1881 he explored the prairie regions, and the town of Macoun in Saskatchewan commemorates his exploits. In 1882 he published an octavo volume of 687 pages, "Manitoba and the Great North West." This, with his report in 1877 on the possibilities of the Peace River region, predicted a development in the future which is only now becoming credible. But the botanist had a scientific basis for his belief in the natural floras of the regions. An agricultural committee of the House of Commons called upon him for information, and after examination presented him on the 23rd of January, 1906, with an engrossed motion of thanks which contained the paragraph: "Optimistic as his reports and prophecies were, they have all proved true. To these are to be added Professor Macoun's explorations in the Canadian Yukon Territory in 1903, which revealed for the first time that that far northern division of Canada also possesses agricultural resources of no mean order."

In 1881 he was appointed Botanist to the Dominion Government, resigned his professorship in Belleville, and next year came with his family to Ottawa, where he resided until 1912. Here his enthusiasm as a naturalist made him a valued member of the Ottawa Field-Naturalists' Club of which he was President in 1886-7. During these 30 years, with the assistance of his son, James M. Macoun, he built up the greater part of the herbarium of over 100,000 Canadian plants which are now in the Victoria Memorial Museum.

His Catalogue of Canadian Plants began to be published in 1883, attaining in 1902 about 1,700 pages from the *Polypetalæ* to the *Hepaticæ.* In 1887 he was promoted to the position of the Assistant Director and Naturalist of the Geological Survey.

Eight years previous he commenced to collect also bird skins for the Museum of the Survey, which now very fully exhibits well mounted specimens of all the birds of Canada. This work was naturally followed by the publication of a Catalogue of Canadian Birds in 1900, concluded in three parts in 1904, and re-edited with the assistance of his son, James M., in 1909, giving the range and breeding habits in addition to the names.



JOHN MACOUN

He published other less known books and numerous reports in his ceaselessly active life, the titles of which would make a lengthy bibliography. He leaves, in an advanced stage of preparation, an "Annotated List of the Flora of the Ottawa Region," an "Annotated List of the Flora of Nova Scotia," and an "Annotated List of the Flora of Vancouver Island," which, it is hoped, may soon be published.

The temperature of Vancouver Island appealed to him as a good part of Canada in which to retire in case of superannuation, where natural history collecting could be enjoyed nearly all the year round. In his eighty-first year, 1912, he finally decided to leave Ottawa for his retiring home. The extra activity and excitement of the occasion may have been responsible for the attack of paralysis which affected his right arm and leg. But he soon recuperated enough to allow himself and wife to leave in April for the West, where he soon was roaming the fields and fells and forests by day and reading by night. He trained his left hand to write effectively, for the other could not be retrained; and for eight years more he enjoyed the wealth and wonder of nature and the association of a friendly public press and appreciative scientific friends. The Government, in view of his long, active and prolific service, allowed him, in 1913, to retain his title, position and connexion with the Department, an act which shows Governments do not always neglect to recognize distinguished service.

John Macoun was Canada's greatest exploring botanist. But he was more than a botanist, as his works show. No Canadian naturalist approached his taxonomic lore. The number of new species discovered by him must be very great, for we find at least a score of flowering plants, and a score of cryptogams named after him, as well as at lease a half a dozen zoological species.

He was a marvel of physical activity, a hospitable entertainer in his home, and the life of any party in which he was entertained. He was frankly outspoken; but his logical opponent was disarmed by his unfailing good humour and natural generosity. His tales of travel and trail were always disclosing interesting features and the economic resources of the country, while thrilling with incident and abounding in humour. He was a revealer of Canada; but he was also a conserver of the Greater Britain whose ultimate goal is to show the world how to govern itself.

In his Church, St. Andrews, Ottawa, he was a Presbyterian elder. But to the people in general he was the enthusiastic explorer of unknown Canada, a reveller in the delights of the living world of

Nature within it, a lover of the beautiful in the sculpture and records of its geologic base and its biologic crown, and in the spirits of his nobler compatriots who are developing the higher civilization.

In the Spring of 1920 his vitality was lowered by a severe attack of whooping cough; but he was not confined to the house by a weakening heart for more than a week before he passed away on the 18th of July, in his ninetieth year.

He was married in 1862 to Miss Ellen Terrill, of Wooler, Ontario, who survived him. His children are: Mrs. A. O. Wheeler, Sidney, B.C.; Mrs. R. A. Kingman, Wallingford, Vt.; Mrs. W. M. Everall, Victoria, B.C.; and Mr. W. T. Macoun, Dominion Horticulturist, Experimental Farm, Ottawa. His eldest son, Mr. James M. Macoun, Chief of the Biological Division of the Geological Survey, predeceased him by only a few months.

IV—Address of Welcome to His Excellency the Governor General

On January 17th a delegation, consisting of the President, Honorary Secretary and several other members of the Council, visited His Excellency the Governor General and presented the following address:—

To His Excellency Baron Byng of Vimy, G.C.B., G.C.M.G., M.V.O.,
Governor General of Canada,
Government House,
Ottawa, Canada.

Sir,

The Royal Society of Canada desires to extend to you a cordial welcome to this country and to express the hope that the close relations with Canadians begun so strenuously under the trying conditions of war will continue and strengthen under the happy conditions of peace.

The Society was founded in the year 1882 by one of your distinguished predecessors in the Office of Governor General, the late Duke of Argyll (then the Marquis of Lorne) and since that time it has been honoured in having as its Patron the Governor General of Canada, during his term of office. Under such distinguished patronage the Society has gradually and consistently extended its sphere of usefulness in the fields of science and of letters.

In order to encourage and reward studies and investigations the Society is empowered to offer prizes and other inducements for meritorious papers on literary and scientific subjects, and these papers, after presentation to the Society, are published in a volume of Transactions issued annually. These volumes now number thirty-eight. They are distributed to libraries and learned societies in Canada and other countries. We feel that Canada may be justly proud of the record contained in them; a record that, no doubt, has had a stimulating effect on investigations, not only in Canada, but throughout the civilized world.

The Society holds annual meetings for the reading and discussion of papers. To these the public is admitted freely, and every effort is made to foster in Canadian life a desire for, and interest in, both æsthetic and scientific culture.

The regulations of the Society adopted under authority of statute provide that the Governor General shall be its Honorary Patron and we venture to hope that Your Excellency will permit us to add your name to the hitherto unbroken line of Governors General who have filled that office. We are convinced that acceptance of this office by Your Excellency will serve to increase the influence and usefulness of the Society throughout the Dominion and to maintain its established prestige.

With renewed assurances of our loyalty and devotion to the Throne and Empire and an earnest wish that the sojourn of Your Excellency in Canada may be a pleasant one, we remain, Sir, with profound respect, Your Excellency's most dutiful and obedient servants.

Signed on behalf of the Council and Fellows of the Society.

CHARLES CAMSELL, *Honorary Secretary.*

DUNCAN C. SCOTT, *President.*

His Excellency replied as follows:—

Mr. President and Gentlemen.

My thanks are due to you for so kindly coming here this morning and it has given me much pleasure to listen to your interesting address.

I greatly appreciate your kind and warm welcome and shall be delighted to become your Honorary Patron as so kindly requested. Since your Society was founded by the late Duke of Argyll in the year 1882, it has steadily grown both in numbers and influence and, needless to say, it will give me great pleasure to forward its objects and aims in any way in my power.

The fields of science and letters are large and there is always more and more to be done. In a comparatively new country like Canada perhaps the importance of science has not always been recognized as it should be—but I feel sure that it is most necessary and in fact vital to the well-being of the country that everything should be done to encourage the study of the same. I have heard, with interest, what you have been and are doing to encourage these arts and am sure that the 38 volumes you have published are eagerly read and studied in many countries besides the Dominion.

I heartily thank you gentlemen for your assurances of loyalty and devotion to the Throne and Empire and for your very kind personal wishes to myself, which I most sincerely appreciate.

V—Nova Scotia Historical Celebration

On behalf of the committee appointed at the last meeting to represent the Society at the Historical Celebration in Annapolis Royal on August 31st last, Brig. General Cruikshank has submitted the following report:—

Ottawa, 27th February, 1922.

The Secretary of The Royal Society of Canada,
Ottawa, Ont.

Sir,

I beg to report that in pursuance of the resolution passed by The Royal Society of Canada at its session held on May 20, 1921, the following members attended as delegates at the triple celebration of historic events at Annapolis Royal, Nova Scotia, on August 31st, 1921, namely, Mr. Justice Longley, Dr. Archibald MacMechan and the writer.

The proceedings comprised the unveiling of three commemorative tablets; the delivery of addresses by Mr. Justice Chisholm, Hon. George Murray, Sir James Aikins, Chief Justice Harris and Hon. F. B. McCurdy; and the reading of three papers on historical subjects at an evening meeting.

The tablets, which were unveiled on a temporary platform erected on the former parade ground within the ramparts of Fort Anne, now a Dominion Park property, bore these inscriptions:

I

This tablet, placed here by the Government of Nova Scotia, A.D. 1921, commemorates the three hundredth anniversary of the issue of the charter of New Scotland, by King James I of England and VI of Scotland, A.D. 1621.

The birth of an idea which lived, and had its final fruition in the taking of this Post and conquest of Acadia in the reign of Queen Anne.

II

This tablet placed here by the Bench and Bar of Canada, A.D. 1921, marks the two hundredth anniversary of the establishment and sitting (in this Fort), A.D. 1721, of the first Court administering English Common Law within what is now the Dominion of Canada.

"Law Hateth Wrong." Wingate Maxims, No. 146.

III

This tablet, erected A.D. 1921, under the auspices of the Historical Association of Annapolis Royal, commemorates the one hundredth anniversary of the arrival in this town of Thomas Chandler Haliburton, who lived here eight years and began in this place his great career in Law, Literature and Public Life.

The ceremony of unveiling was performed by the Hon. MacCallum Grant, Lieutenant Governor of Nova Scotia. Many people were present, and the weather was all that could be wished for.

Mr. Justice Chisholm, President of the Nova Scotia Historical Society, presided at the evening meeting, when lengthy papers were read on "The Royal Charter of Sir William Alexander," by Dr. Alexander Fraser, Archivist of Ontario; "The Relations of the British Dominion of Virginia with the Dominion of Canada," by Dr. John Murray Clark, K.C., of Toronto; and "On the Courts and the Commonwealth," by Dr. Charles Morse, K.C., of Ottawa.

Mr. Justice Longley moved a vote of thanks on behalf of the visitors.

Respectfully submitted,

E. A. CRUIKSHANK.

VI—Museum Accommodation

In pursuance of the resolution passed at the last meeting requesting the Government to approve of the appointment by the Society of a committee to draw up a plan of organization for an adequate Canadian National Museum, the Council have to report that on February 1st, last, representations were made to the Hon. W. L.

MacKenzie King, C.M.G., the Prime Minister, asking for approval of the appointment of such a committee. The Prime Minister replied expressing his whole-hearted sympathy with the project but intimating that he did not consider the time opportune for the Society to ask his colleagues and himself to contemplate further expenditure on public buildings, but that more favourable consideration might be expected at a later date. The President replied thanking the Prime Minister and suggesting that a committee might be asked to prepare a report. Such a committee was named by the President on March 7th and due notification given to each member. The committee, it is presumed, will meet during the course of the present annual meeting.

VII—Report of the Honorary Librarian

The exchanges received throughout the year at the library are delivered at present in monthly shipments. These have been stored in a separate room along with those of last year, an estimate of which was given in the report for 1921.

During the last few weeks temporary assistance has been secured and an estimate of the year's receipts has been prepared. The accumulation of the last two years, it is hoped, will now be indexed and it is propsed to remove from the shelving and store securely such exchanges as do not appear to be of interest, such as Russian or other material not easily translated or liable to be consulted so as to make room for current issues which are of interest as showing advances in different lines of investigation.

The estimate as prepared shows the receipts as being somewhat smaller than for the previous year, which was estimated at 1,106 publications. This year the receipts are 905, a falling off principally from countries outside the British Empire. The reduction from many of the European States reflects the general economic condition; but other and more serious causes are indicated in the elimination of others, such as Russia and the decline in exchanges from Germany and Austria. The library contains about 12,000 volumes, of which, it is estimated, there are about 2,100 bound. The rest are in paper covers and many are in separate parts.

It is recommended that a contract for binding be considered as soon as the finances of the Society permit.

Volumes and separate publications received for the year.....905

Bound Volumes received in the above estimate............. 36

D. B. Dowling,
Hon. Librarian.

VIII—Report of the Honorary Treasurer

The following report, which includes the Government Grant Account and the General Account, covers the year ending April 30th, 1922. It has been audited by Dr. J. C. Glashan and Dr. Adam Shortt, who were appointed for that purpose.

FINANCIAL STATEMENT OF THE ROYAL SOCIETY OF CANADA FOR THE YEAR ENDING APRIL 30, 1922

GOVERNMENT GRANT ACCOUNT

Receipts

By Balance in The Bank of Montreal, April 30, 1921	$1,796.48
" Grant from The Dominion Government	8,000.00
" Grant from the Hon. Advisory Council for Scientific and Industrial Research	3,000.00
" Bank interest on account	191.40
	$12,987.88

Expenditure

To Printing and publication of *Transactions*	$7,122.01
" Transfer to Current Account	4,000.00
" Clerical Assistance	748.00
" Insurance	43.80
" Miscellaneous expenditure (mailing, shipping, etc.)	248.89
" Balance in The Bank of Montreal, May 1, 1922	825.18
	$12,987.88

GENERAL ACCOUNT

Receipts

By Balance in The Merchants' Bank of Canada, April 30, 1921	$2,308.81
" Annual Subscriptions and Initiation fees	1,661.67
" Transfer from the Government Account	4,000.00
" Sale of Transactions	37.65
" Interest on investments	597.20
" Bank interest on account	39.84
" Refund of Assist. Secret.'s cheque for Oct. salary	50.00
	$8,695.17

Expenditure

To Railway fares of Fellows	$1,477.78
" Investment in Dominion Government bonds (inclus. of interest and cost)	5,136.00
" Expenses of Annual Meeting	148.60
" Miscellaneous expenditure	62.76
" Oct. salary cheque for Asst. Secretary	50.00
" Balance in the Merchants' Bank of Canada, April 29, 1922	1,820.03
	$8,695.17

Audited and found correct:

J. C. GLASHAN } *Auditors.*
ADAM SHORTT }

C. M. BARBEAU,
Honorary Treasurer.

Ottawa, May 2, 1922.

When the Honorary Secretary had finished reading the Report it was moved by Mr. Burpee, seconded by Dr. Coyne, that the Report of Council be received and that the question of adoption be voted on to-morrow.—Carried.

It was moved by Hon. Thomas Chapais, seconded by L'Abbe Camille Roy, that the election of Mgr. J. M. Emard and Dr. C. J. Magnan as Fellows of Section I be confirmed.—Carried.

It was moved by Brig.-Gen. E. A. Cruikshank, seconded by Professor George S. Brett, that the election of Dr. W. S. Fox, Mr. J. M. Gibbon and Dr. E. Sapir as Fellows of Section II be confirmed.—Carried.

It was moved by Mr. J. Patterson, seconded by Professor Frank Allen, that the election of Dr. J. A. Gray, Dr. A. Ll. Hughes and Dr. Otto Maass as Fellows of Section III be confirmed.—Carried.

It was moved by Dr. A. P. Coleman, seconded by Dr. D. B. Dowling, that the election of Dr. John A. Allan, Mr. W. A. Johnston and Dr. S. J. Schofield as Fellows of Section IV be confirmed.—Carried.

It was moved by Professor F. E. Lloyd, seconded by Dr. Andrew Hunter, that the election of Mr. Arthur Gibson, Dr. V. J. Harding, Dr. F. R. Miller, Dr. James Miller, Dr. C. H. O'Donoghue and Dr. John Tait as Fellows of Section V be confirmed.—Carried.

The following new Fellows were introduced: Dr. Magnan, Dr. Fox, Mr. Gibbon, Dr. J. A. Gray, Dr. A. Ll. Hughes, Dr. Otto Maass, Mr. Johnston, Dr. Harding, Mr. Gibson and Dr. James Miller, as well as Dr. Wallace, who was elected last year.

Printed copies of the notice of motion for amendment to the by-laws, submitted by the President and the Honorary Secretary, were then distributed. This amendment had reference to Section 8 dealing with the duties of members, especially in respect to the submission of papers and attendance at the annual meeting. After a short discussion the President asked the different sections to take the matter into consideration and report at a later session.

The President drew attention to a resolution passed at the meeting of the Council on the 16th instant regarding the presentation of papers, which read as follows:

"That the Council draw the attention of the Fellows of the Society and of the Secretaries of the Sections particularly to the provisions of the by-law relating to the submission of papers to the Society for publication, viz., By-law 18, and inform the Fellows that the Council will in future enforce the rule in the interest of prompt publication. In order that no hardship shall occur from ignorance of the by-law the time shall be extended this year to June 15."

The Sections were asked to give consideration to this matter and report at a subsequent session.

Mr. Patterson, Secretary of Section III, read a communication from the Librarian of the University of Toronto to Dr. J. C. McLennan regarding the sales tax on scientific books imported from Germany and Austria, and asking him when in Ottawa to arrange for a deputation to wait upon the Minister of Customs to make representations to have this tax based upon the actual cost of shipment from foreign countries instead of on the estimated value of fifty per cent. of the pre-war rate of exchange.

The following resolution was then presented:—

"The Royal Society of Canada, at its general meeting on May 17th, 1922, desires to place itself on record as strongly supporting the request of the President of the University of Toronto to the Minister of Customs that the Universities should be allowed to pay a sales tax upon the actual cost to them of shipments from foreign countries instead of upon the estimated value of fifty per cent. of the pre-war rate of exchange; and we further advocate that this privilege should be extended to scientific organizations. It is also resolved that each Section be requested to name a representative to go on the deputation to the Minister in regard to the subject."

It was moved by Mr. Patterson, seconded by Dr. Eve, that the resolution be adopted.—Carried.

A committee was appointed, and their report will be found in the Minutes of Thursday afternoon session.

The following motion was then introduced by Dr. Harrison, seconded by Dr. Currelly:—

That a committee be appointed to wait upon the Minister of Finance to ask that:—

"In computing net income a deduction from gross income be allowed individuals for contributions or gifts made within the taxable year to any corporation or community chest, fund or foundation organised and operated exclusively for scientific, literary or educational purposes.

"The allowance for such contributions be limited to not exceeding 15% of the individual taxpayer's net income as computed without the benefit of this deduction.

" Corporations should not be entitled to deduct gifts of the kind described.

"This should not be applicable to amounts that total less than one thousand dollars."

After some discussion it was suggested by the President that this matter should be referred to a committee. This was agreed to and the President appointed the following Fellows a committee to consider the resolution and report thereon: The Mover, the Seconder, Dr. Shortt, Dr. Wrong and Canon Chartier.

It was moved by Dr. A. T. Cameron, seconded by Dr. F. J. Lewis, that the Sections consider and report on the desirability of publishing the Transactions in two parts—one, the Transactions of Sections I and II; the other, the Transactions of Sections III, IV and V.

The Presidential Address— (*Wednesday Evening, May 17*)

The Presidential Address was delivered on Wednesday evening in the Victoria Memorial Museum in the presence of the Honorary Patron, His Excellency Baron Byng of Vimy and a large audience. The chair was occupied by the Vice-President, Dr. J. Playfair McMurrich. The President's subject was "Poetry and Progress." The Address will be found printed in full as Appendix "A."

SESSION II—(*Thursday Afternoon, May 18*)

The President took the chair.

It was moved by Dr. Young, seconded by Professor Hill-Tout, that the Report of Council be adopted.—Carried.

The reports of the following associated societies were then presented:—

The Women's Wentworth Historical Society, Royal Astronomical Society of Canada, Ontario Historical Society, The Huron Institute, Lundy's Lane Historical Society, The Women's Canadian Historical Society of Toronto, The Alumnae Association of the Hamilton Ladies' College, The Niagara Historical Society, Elgin Historical and Scientific Institute, Hamilton Scientific Association, Natural History Society of Montreal, La Société Historique de Montreal, Antiquarian and Numismatic Society of Montreal, The Nova Scotia Historical Society, The Nova Scotian Institute of Science, Natural History Society of British Columbia.

Dr. A. H. MacKay, who had prepared a sketch of the work of the late Professor John Macoun, M.A., F.L.S., was then called upon by the President and delivered the following address:—

A CHARTER MEMBER'S WORK (1831-1921): PROFESSOR JOHN MACOUN, M.A., F.L.S., CANADIAN NATURALIST AND EXPLORER

Forty years of preparation, forty years of feverish exploration across prairies and mountains from ocean to ocean, and nearly ten of quiet enjoyment—but still exploring—in his Western Island retreat by the Pacific, sum up the career of a remarkable unit of human energy which came to Canada from beyond the Atlantic—from Ireland on the west of Europe.

"His blue eyes sought the West afar
For lovers love the Western star."

He came to a pioneer Canadian farm at nineteen, but was soon drafted into the leadership of the young as a teacher, his preparation culminating in promotion to the professorship of Natural History subjects in Albert College, Belleville, Ontario, at forty.

In 1872 he was spending his vacation as usual, this time on a botanical excursion across the great lakes to the then new west, when he collided with the Sir Sanford Flemming Expedition in search of a transcontinental railway route, Rev. Geo. M. Grant of Halifax being secretary. His enthusiastic personality, with its untiring energy and scientific competency, was a great desideratum of the expedition so that he was promptly annexed, to the delight and profit of all, as is graphically sketched in Grant's "Ocean to Ocean."

This was the first of more than a dozen exploratory excursions across the continent. Macoun's chief botanical interest, as would anyone's be when coming into new territory, was the discovery of what was *there*. He found an interesting flora of which most species were already described by the earlier botanists. But the general complexion of these floras varied with the geological substratum and the physical conditions and exposures of the localities. Among these were many new forms not previously described. He was forced to know exactly the natural exterior morphology of plants and their ecological relations.

He therefore had not time to expend on the minute structures necessary for the study of plant physiology and the problems of genetics. His interests were absorbed in the morphology, taxonomy and ecology of vegetation, and of the zoological species collected. The floras and faunas existing were conditioned by the geological and meteorological environment which together largely determined the possibilities of the economic development of the country.

Pure science became thus the grounds of his recommendations to those ready to open up the country for settlement. But the settler with his small capital had to be aided by the railroad builder in order to get into these vast but remote regions where human industry could not only exist but expand. Thus we find our explorer continually transcending his scientific lists of species of plants and animals by publishing descriptions of the new regions fitted for the occupation of man.

Of these publications the more important may be his report on the country between Port Arthur and the Pacific in 1877, the Peace River district, and his book, "Manitoba and the Great North-West," 687 pages, published about 1882. In 1906 a committee of the House of Commons called him before them for examination with special reference to the agricultural possibilities of the North-West. They presented him (January 23rd, 1906) with an engrossed vote of thanks which contains the paragraph: "Optimistic as his reports and prophecies were they have all proved true. To these are to be added Professor Macoun's explorations in the Canadian Yukon territory in 1903, which revealed for the first time that that far northern division of Canada also possesses agricultural resources of no mean order."

In 1879 Albert College had to give up its exploring professor altogether, but kept him on the roll as Professor *Emeritus*. In 1881 he was appointed Botanist to the Dominion, and next year removed his home to Ottawa, where it remained for the next thirty years, although his summers were for thirty years spent in the field until 1903.

In 1882 I first met him in Pictou, when he was accompanied by his young son, James M., then about nineteen, whom his father proudly referred to as a genius in detecting any new form. It was with his aid he built up at Ottawa subsequently the greater part of the national herbarium of over 100,000 Canadian plants now in the Victoria Museum. He also became, with his sons later, a stimulating member of the Ottawa Field Naturalists Club, which in turn communicated some of its impetus to the scientific centres of the other Provinces.

In 1883 he commenced publishing his Catalogue of Canadian Plants, which appeared every year or two in parts as follows: Polypetalae, 1883; Gamopetalae, 1884; Apetalae, 1886; Endogens, 1888;

Acrogens, 1890; Musci, 1892; Lichenes and Hepaticae, 1902. The series contains about 1,700 pages.

During this time he was actively employed, especially in summers, in exploring the country from Sable Island in the Atlantic, where a new fresh water sponge (*Heteromeyenia Macouni* McK.) was collected by him in the solitary lagoon in the sand, through Cape Breton, Nova Scotia, across the Continent and over the Rockies to Vancouver Island and the inhospitable Yukon. He photographed the forest trees of British Columbia which he could not carry with him, named the animals and birds sighted as well as the plants, and came to Ottawa with his treasures.

In 1887 his work was recognized by his appointment by the Government as Assistant Director and Naturalist of the Geological Survey. His collections of Bird Skins were mounted, and contributed largely to complete the collection now in the Museum. In 1900 he commenced the publication of a Catalogue of Canadian Birds, the second part in 1903, the third part in 1904. On the exhaustion of these editions a revision of the whole, with the range and breeding habits of each species, was published in 1909 with the assistance of his son.

He published an "Elementary Botany" for schools. But his flora of the Atlantic Provinces, which the respective Education Departments hoped to utilize in connexion with the public schools, has not yet been printed. Annotated lists of the Flora of Ottawa, and of Vancouver Island are also yet unpublished. At least forty species of plants and a half a dozen zoological species have been named after him by contemporary naturalists. A committee of the Privy Council, June 9, 1913, allowed him to retain his connexion with the Department of Mines, which would be severed by the superannuation regulations, in recognition of his eminent services. From this date he continued to enjoy working up the cryptogams of Vancouver Island—more gently with the growing disabilities of age, but still with the joy of the sportsman, the satisfaction of the naturalist and the enrichment of science. He presented a valuable Herbarium of varied plants to the Provincial Government of British Columbia at Victoria. He always enjoyed the satisfaction of the public appreciation. His opportunities for similar exploration can never exist again. Yet there are boundless other fields of exploration beckoning to the votaries of science in Canada to-day. No great explorer of Nature exhausts the field. He only opens to view many other boundless areas. But no succeeding naturalist is likely to surpass the record of John Macoun's motile energy in exploration and carry in his mind's eye more numerous distinct images of definite specific forms of Nature's workmanship.

Professor Prince, Professor R. B. Thomson and Dr. Coyne spoke after Dr. MacKay had finished reading his address, all referring in most eulogistic terms to the character and work of Dr. Macoun.

The matter of amendment to the By-laws was again taken up. Section III, through Mr. Patterson, suggested a change in the amendment as originally proposed, and Section IV, through Dr. Young, recommended that the original By-law stand. It was then decided that the recommendations of Section III should be printed and distributed to the Sections. This was done.

The Committee appointed by the President to consider the resolution introduced at the first session by Dr. Harrison and Dr. Currelly reported that they had met and appointed Dr. Shortt and the Honorary Secretary to interview the Minister of Finance at some time that would be convenient to him after the conclusion of the debate on the Budget.

It was moved by Dr. Parks, seconded by Dr. Young, on behalf of Section IV, that the Royal Society of Canada has learnt with regret that the Government of Canada proposes to send only one representative to the International Geological Congress Meeting in August in Belgium. The Society is of the opinion that at least two representatives chosen from the Department of Mines should be sent to the Congress and authorizes Dr. F. D. Adams, Dr. A. P. Coleman and Mr. J. D. Dresser as representing the Society, to present this view of the matter to the Honourable Charles Stewart, Minister of Mines, and urge that the Government reconsider its decision.—Carried.

It was moved by Dr. Parks, seconded by Dr. Young, on behalf of Section IV, that the following members of Section IV, namely Frank D. Adams, Henry M. Ami, Reginald W. Brock, Charles Camsell, A. P. Coleman, Willet G. Miller, William Arthur Parks and Thomas L. Walker be appointed members of a Delegation from the Royal Society of Canada to the session of the International Geological Congress to be held in August of this year in Belgium and that the Honorary Secretary be empowered to add to the numbers of this Delegation any other members of Section IV who may signify their intention of attending the same session of this Congress.—Carried.

Some consideration was then given to the dates usually set for the Annual Meeting. It was decided to leave the matter for further consideration by the Sections. Dr. Murray suggested that the next Annual Meeting should take place at some point west of the Great

Lakes, and Dr. Barbeau intimated that an invitation would be extended to the Society to meet in 1924 in the city of Quebec.

Professor Wrong, on behalf of the committee appointed to interview the Government regarding sales tax on books imported from foreign countries, reported that the Minister of Customs had promised to make the change requested.

THE POPULAR LECTURE—(*Thursday Evening, May 18*)

The annual Popular Lecture was given in the Victoria Memorial Museum before the Fellows and guests of the Society by Professor S. E. Whitnall, of McGill University.

Professor Whitnall entertained a large audience by the interesting treatment of his subject, "The Evolution and Use of the Brain."

SESSION III—(*Friday Afternoon, May 19*)

The President took the chair at 3 p.m. and called for the Reports of the Sections.

REPORT OF THE SECTIONS

SECTION I

PROCES-VERBAL DE LA SECTION I

Membres présents: MM. Pierre-Georges Roy, Aegidius Fauteux, Thomas Chapais, Léon Gérin, Marius Barbeau, MM. les abbés Camille Roy, Ivanhoë Caron, M. le Chanoine Emile Chartier, MM. A.-D. DeCelles, L.-O. David, Rodolphe Lemieux, C.-J. Magnan, Georges Pelletier et Antonio Perrault.

Travaux lus ou résumés:

1. Le Régiment de Carignan, par Francis-J. Audet.
2. Un problème de linguistique canadienne, par l'abbé Arthur Maheux.
3. Une polémique à propos d'éducation en 1820, par l'abbé Ivanhoë Caron.
4. Les Chevaliers de Saint-Louis au Canada, par Aegidius Fauteux.
5. Deux poèmes, par l'abbé Arthur Lacasse.
6. Les origines sociales de l'habitant, par Léon Gérin.

7. Légendes de Percé, par Claude Melançon.

8. A propos du livre sur Louisbourg du Sénateur McLennan—Les retours de l'histoire (hors programme), par l'Hon. M. Rodolphe Lemieux.

9. Principe et pratique de la représentation dans la Nouvelle-France, par Gustave Lanctot.

10. Au berceau de notre histoire; un brin de critique historique et littéraire, par l'abbé H.-A. Scott.

11. Louis-Raymond Giroux (1841-1911), par le juge L.-A. Prud'homme.

12. La sociologie et la morale, par l'abbé Arthur Robert.

13. La paroisse canadienne jugée par un evêque de France, par l'abbé Elie-J. Auclair.

14. D'Iberville et la conquête de la Nouvelle-France, par le Sénateur L.-O. David.

15. La vie des "chantiers," par E.-Z. Massicotte.

16. La "Cloche de Louisbourg" du docteur Nérée Beauchemin, par le Chanoine Emile Chartier.

17. Migrations du choléra asiatique, par Mgr. David Gosselin.

18. Poésies, par Alphonse Désilets.

Pendant les séances on proposa et accepta les résolutions suivantes:

—D'accorder un délai d'un an à M. Massicotte pour lui permettre de se conformer aux règlements relatifs à la présentation d'un nouveau membre dans les trois premières années qui suivent son élection.

—De rendre hommage à la mémoire de feu M. Adolphe Poisson, qui fut longtemps un de ses membres, et d'offrir à sa famille un témoignage de profonde sympathie.

—De demander au conseil général d'établir trois vacances en tout pour l'élection des candidats au cours du prochain exercice.

La Section I approuva l'amendement à la Section 8 de la constitution tel que proposé, et se prononça en faveur de la forme actuelle de publication des *Transactions* de la Société; les travaux présontés devront à l'avenir être remis en séance.

Des représentants de la Section se joignirent aux délégations auprès des Ministres des Finances et des Douanes, au sujet des taxes d'achat sur les livres de l'étranger et des taxes successorales sur les donations destinées aux fins scientifiques et littéraires.

Election des dignitaires pour l'année nouvelle:

Président: M. le Chanoine Emile Chartier;

Vice-Président: M. Pierre-Georges Roy;

Sécrétaire: M. Aegidius Fauteux.

Comité de Lecture: MM. Aegidius Fauteux, le Chanoine Emile Chartier et l'abbé Elie-J. Auclair.

Délégues au bureau d'élection des dignitaires généraux de la société: MM. A.-D. DeCelles et Aegidius Fauteux.

C.- Marius Barbeau,
Sécrétaire de la Section I.

On motion of Mr. C. M. Barbeau, seconded by Canon Emile Chartier, the report of Section I was adopted.

REPORT OF SECTION II

The Section held four sessions, on the 17th, 18th and 19th May, in the Print Room of the National Gallery. The following Fellows were in attendance: Messrs. Brett, Bryce, Burpee, Coyne, Currelly, Cruikshank, Doughty, Fox, Gibbon, Hill-Tout, Howay, King, Lighthall, MacIver, MacPhail, Mavor, Macnaughton, Murray, Oliver, D. C. Scott, Shortt, Skelton, Stewart and Wrong. In the unavoidable absence of the President, Mr. Justice Riddell, Mr. Hill-Tout presided.

On motion the following resolution was unanimously adopted: That on the occasion of the recent retirement from active official duty, after an almost unprecedented record of public service extending over nearly half a century, of Colonel George Taylor Denison, a member of this Section, and a charter member and former president of the Royal Society, we desire to express our high appreciation of his character and honourable and useful achievements, and to express the hope that he may be long preserved to enjoy his well-earned retirement, and the continued esteem of the Canadian people whom he has served so long and so well. And that a copy of this resolution be forwarded to Colonel Denison.

Mr. Lighthall was appointed the representative of the Section on the general Nominating Committee.

The operation of By-law No. 8 was suspended in order to retain the names of Colonel George T. Denison, Sir Edmund Walker, and Rev. Canon Scott on the list of Active Members.

It was decided to elect three new members during the ensuing year.

Mr. Gibbons was appointed to represent the Section on the deputation to interview the Minister of Customs in the matter of the sales tax on scientific books for educational institutions.

The Section discussed the question of the Society's publications, and decided to recommend that in future the annual volume should be bound in two parts, one to contain the Transactions of Sections I and II and the other the Transactions of Sections III, IV and V.

In regard to the proposed amendment of By-law 8, the Section approves of the original draft amendment submitted by the President and Honorary Secretary of the Society, with the elimination of the word "scientific" in the second line, which it considers superfluous and invidious. In the alternative amendment it particularly objects to the principle that Fellows who fail to live up to either the letter or spirit of the By-laws should be rewarded by transfer to the Retired List. That would in effect be putting a premium on delinquency.

The Section recommends that the Dominion Government be requested to authorize the reciprocal exchange of photostatic or other copies of documents in the Public Archives of Canada and in other public institutions, to the end that students may have accessible either the originals or authentic copies of the documents relating to each province, within that province.

The Section recommends that any Fellows who may find it convenient to attend the ceremonies in connection with the unveiling of the monument at Port Dover commemorating the first discovery of Lake Erie, or any other ceremonies during the forthcoming year in connection with the marking of historic sites or buildings, be authorized to appear as representatives of the Royal Society.

The Section put upon record its profound regret because of the death of Hon. Mr. Justice Longley, one of the oldest and most active members of the Section and of the Society, and directed the Secretary to communicate to Mrs. Longley and the other members of the family an expression of their sympathy.

The Section recorded its regret because of the inability of Mr. Justice Riddell, President of the Section, to attend this year's Meeting.

The question of how papers could be most effectively put before the Section was discussed at length, and it was the feeling of the Section that it would add materially to the value of the annual meeting if papers could be read in the form of a reasonably full abstract. The decision was reached that in future members submitting papers to the Section should be allowed not more than fifteen, or at the outside twenty minutes to put the paper in condensed form before the Section. This would leave more time for discussion, and would not interfere with the subsequent publication of the paper in full.

The Section put itself upon record as favouring any means which might be found practicable for bringing about closer relations with Section I.

The Section took up the question of the date of the annual meeting, but felt that it was a matter rather for discussion at a general meeting of the Society, and therefore offers no recommendation as a Section.

Mr. Currelly brought up the matter of the preservation of historic buildings in England and their accessibility to the public, and suggested that a sub-committee might be appointed to draft a communication to the Imperial Government expressing the views of the Royal Society. The Section felt, however, that it was improper for the Royal Society to interfere in what was essentially a domestic question for the Mother Country.

The Advisory Committee on Nominations for the Section was elected as follows: Dr. Shortt, Prof. Edgar, Dr. Coyne, Dr. Lighthall, Dr. MacMechan, Prof. Martin and Judge Howay.

The Printing Committee of the Section consists of the following: Mr. Burpee, Dr. Morison and Gen. Cruikshank.

The following officers were elected: President, Prof. Hill-Tout; Vice-President, Judge Howay; Secretary, Mr. Burpee.

The following papers were read, in extenso, in the form of a summary, or by title:

1.—Presidential Address. Upper Canada a Century Ago. By Hon. William Renwick Riddell, LL.D., F.R.S.C.

2.—A chapter of Canadian economic history, 1791 to 1839. By James Mavor, Ph.D., F.R.S.C.

3.—University development in Canada. By Walter C. Murray, M.A., LL.D., F.R.S.C.

4.—Frederic Harrison and the religion of humanity. By Herbert L. Stewart, M.A., Ph.D., F.R.S.C.

5.—Why Pickwick was gaoled. By Hon. William Renwick Riddell, LL.D., F.R.S.C.

6.—The Bohemian settlement of Glenside. A study in the origins of a Saskatchewan community. By Rev. Edmund H. Oliver, M.A., Ph.D., F.R.S.C.

7.—Earliest route of travel between Canada and Acadia. Old time celebrities who used it. By Ven. Archdeacon W. O. Raymond, LL.D., F.R.S.C.

8.—London to Toronto in 1836. By Hon. William Renwick Riddell, LL.D., F.R.S.C.

9.—A forgotten loyalist; Lieutenant General Garret Fisher (1742-1808). By William Douw Lighthall, M.A., B.C.L., F.R.S.L., F.R.S.C.

10.—The relations of the confederacy of Western Indians with the Government of Canada, from 1785 to 1795. By Brigadier General E. A. Cruikshank, LL.D., F.R.S.C.

11.—Shelley's use of philosophical traditions. By George S. Brett, M.A. (Oxon.), F.R.S.C.

12.—The misunderstanding of Samuel Butler. H. Ashton, LL.D. Presented by Judge Frederick William Howay, LL.D., F.R.S.C.

13.—A forgotten Canadian poet. By Hon. William Renwick Riddell, LL.D., F.R.S.C.

14.—Mr. Pepys on Himself. By Lawrence J. Burpee, F.R.G.S., F.R.S.C.

15.—Canada and the government of the tropics. By W. Lawson Grant, M.A. (Oxon.), F.R.S.C.

16.—The Bidwell Elections. By Hon. William Renwick Riddell, LL.D., F.R.S.C.

17.—The "Ordinary" Court of Chancery in Upper Canada. By Hon. William Renwick Riddell, LL.D., F.R.S.C.

18.—Raison d'être of Forts Hope and Yale. By Judge Frederick William Howay, LL.D., F.R.S.C.

19.—The Westmount "Stone-lined Grave" race; an archæological note. By William Douw Lighthall, M.A., B.C.L., F.R.S.L., F.R.S.C.

20.—The legislature of Upper Canada and Contempt. By Hon. William Renwick Riddell, LL.D., F.R.S.C.

21.—"His Honour" the Lieutenant Governor and "His Lordship" the Justice. By Hon. William Renwick Riddell, LL.D., F.R.S.C.

22.—The Stonor Letters and Papers. By W. J. Sykes, B.A. Presented by Brigadier General E. A. Cruikshank, F.R.S.C.

23.—Glebe and School Lands in Prince Edward Island. By D. C. Harvey, M.A. (Oxon.), and presented by Chester Martin, M.A. (Oxon.), B.Litt. (Oxon.), F.R.S.C.

24.—The Colonial Policy of the Dominion. By Chester Martin, M.A. (Oxon.), B.Litt. (Oxon.), F.R.S.C.

On the motion of Mr. Burpee, seconded by Dr. Coyne, the report of Section was adopted.

REPORT OF SECTION III

The Section held five sessions which were attended by the following Fellows: Bain, Mackenzie, Fields, Parker, Boswell, McLennan, Glashan, Herdt, Ruttan, Hughes, Patterson, Eve, King, Boyle, Maass, Gray, Plaskett, Allen, Buchanan, Clark, Allan, Archibald, Johnson, Sullivan, Shutt, Harkness, DeLury, Bronson and several visitors.

Three new Fellows were elected during the past year: Dr. J. A. Gray, Dr. A. Ll. Hughes and Dr. Otto Maass.

The Secretary reported that Dr. Tory had not attended a meeting for three years nor presented a paper, and on motion it was resolved to ask the Society postpone action for one year.

There was a long discussion on the proposed amendment to By-law No. 8, and it was finally agreed to recommend to the Society that the amendment be accepted with the changing of the words from "time to time" to "once in three years or attend the Annual Meeting once in three years," and to give the Section power to place a member who was unable to comply with the By-law, on the retired list, *honora causa.*

The Section heard with very evident satisfaction the decision of the Council to appoint a Committee to report on the best method of publishing the transactions, and approved the recommendation of the Associate Committee on Physics and Engineering Physics of the Honorary Advisory Council that the Scientific papers be published.

(1) In periodical form.

(2) At stated, regular intervals.

(3) For sale at a fixed price and that an Editor-in-Chief and Associate Editors be appointed to superintend the publication as above.

They further recommended that separate publication be made of the papers in Section III.

In regard to the recommendation of Section V on Publication, it was resolved to accept item I, but that no action should be taken on II, pending the report of the Publication Committee to be appointed.

The Section recommends holding the Annual Meeting during the week of May 24th and including that date if necessary.

The President, Professor J. Watson Bain, and the Secretary, Mr. J. Patterson, were appointed to be the Editorial Committee with instructions to refer the papers for publication to any Fellow of Section III and in case of doubt to get the opinion of more than two Fellows.

The representatives on the General Printing Committee for the ensuing year are Professor J. Watson Bain and Mr. John Patterson.

In regard to the Membership Committee it was resolved to retire two members by rotation in alphabetic order and the committee this year to consist of: Professor J. C. McLennan, Mr. J. Patterson, Dr. R. F. Ruttan, Professor Buchanan and Dr. King, the first two on the list to retire next year.

It was resolved that all vacancies occurring in Section III, in addition to the three vacancies allowed by the increase in membership, be filled in the usual manner at the Annual Elections.

Professor A. S. Eve and Professor R. W. Boyle were appointed the representatives of the Section on the General Nominating Committee of the Society.

The election of officers for the ensuing year resulted as follows: President, Professor J. Watson Bain; Vice-President, Dr. J. S. Plaskett; Secretary, Mr. John Patterson.

The following papers were read at the Sessions of the Section:

1.—The Alkali Content of Soils as Related to Crop Growth. By Frank T. Shutt, D.Sc., F.R.S.C., and Alice H. Burwash, B.A.

2.—The Vertical Rise of "Alkali" under Irrigation in Heavy Clay Soils. By Frank T. Shutt, D.Sc., F.R.S.C., and Alice H. Burwash, B.A.

3.—The Partial Oxidation of Methane in Natural Gas. By R. T. Elworthy, B.Sc., A.I.C. Presented by F. T. Shutt, F.R.S.C.

4.—The Formation of Unsaturated Hydrocarbons from Natural Gas. By R. T. Elworthy, B.Sc., A.I.C. Presented by F. T. Shutt, D.Sc., F.R.S.C.

5.—Esters of Palmitic and Stearic Acids. By G. Stafford Whitby and W. R. McGlaughlin. Presented by Dr. R. F. Ruttan, F.R.S.C.

6.—A new Sterol Colour Reaction. By George Stafford Whitby. Presented by Dr. R. F. Ruttan, F.R.S.C.

7.—The Intermediate Compounds in the Reaction between Phthalic Anhydride, Aluminium chloride and aromatic hydrocarbons. By T. C. McMullen, M.A. Presented by Prof. F. B. Allan, F.R.S.C.

8.—The Electrolysis of Copper Sulphate with Interrupted and with Periodically Reversed Currents. By Prof. J. T. Burt-Gerrans and Mr. A. R. Gordon. Presented by Prof. W. Lash Miller, F.R.S.C.

9.—The Periodic Phenomena at the Anode during Electrolysis of Aqueous Solutions of Sodium Sulphide. By W. R. Fetzer, M.A. Presented by Prof. W. Lash Miller, F.R.S.C.

10.—Reactions of Zircon in the Electric Furnace. By I. M. Logan, B.A.Sc. Presented by Prof. W. Lash Miller, F.R.S.C.

11.—The Characteristics of Electric Furnace Arcs. By A. E. R. Westman, B.A. Presented by Prof. W. Lash Miller, F.R.S.C.

12.—The Melting Interval of Certain Undercooled Liquids. By Prof. J. B. Ferguson. Presented by Prof. W. Lash Miller, F.R.S.C.

13.—The Quantitative Determination of Bios. By G. H. W. Lucas, B.A. Presented by Prof. W. Lash Miller, F.R.S.C.

14.—The Effect of Acids on the Rate of Reproduction of Yeast. By Miss E. Taylor, B.A. Presented by Prof. W. Lash Miller, F.R.S.C.

15.—The Reaction of acenaphthene with phthalic anhydride and aluminium chloride. By F. Loriman, B.A. (under direction of Prof. F. B. Allan). Presented by Prof. W. Lash Miller, F.R.S.C.

16.—Researches in Physical and Organic Chemistry Carried out in the Chemical Laboratory of the University of Toronto during the past year. Presented by Prof. W. Lash Miller, F.R.S.C.

(*a*) Some derivative of maleic and fumaric acids. By H. Oddy, M.A. (under direction of Prof. F. B. Allan).

(*b*) Preparation of dust-free salt solutions by C. M. Anderson (under the direction of Prof. F. B Kenrick).

(*c*) Supersaturated solutions of gases. By K. L. Wismer, B.A. (under direction of Prof. F. B. Kenrick).

(*d*) The behaviour of glass on electrolysis. By J. W. Rebbeck, M.A. (under the direction of Prof. J. B. Ferguson).

(*e*) The diffusion of helium through silica glass at high temperatures. By G. A. Williams, M.A. (under direction of Prof. J. B. Ferguson).

(*f*) Stability relations of the lower oxides of iron. By D. M. Findlay, B.A., and I. Hoover (under the direction of Prof. J. B. Ferguson).

(*g*) The electrodeposition of metals on aluminium by T. E. Everest (under direction of Prof. J. B. Ferguson).

(*h*) Investigation of the "throw" at the cathode in copper cyanide solutions. By A. H. Heatley (under direction of Prof. J. T. Burt-Gerrans).

(*i*) The micro-structure and hardness of aluminous abrasives. By C. Hamilton (under direction of Prof. J. T. Burt-Gerrans).

(*j*) The determination of small amounts of zinc and the comparison of various methods for determining phosphorus in phosphor bronze. By Miss F. Burwash (under direction of Prof. L. J. Rogers).

17.—The Mutual Solubility of Liquid Sulphur Dioxide and Hydrocarbons. By W. F. Seyer, Ph.D., and Violet Dunbar, B.A. Presented by E. H. Archibald, F.R.S.C.

18.—Note on the Spreading of Oils on Water. By R. S. Jane. Presented by E. H. Archibald, F.R.S.C.

19.—The Hydrolytic Decomposition of Potassium Bromoplatinate. By E. H. Archibald, F.R.S.C., and W. A. Gale.

20.—On the Excitation of Characteristic X-ray, from Light Elements. By Prof. J. C. McLennan, Toronto, and Miss M. L. Clark, B.A.

21.—On the Liquefaction of Hydrogen and of Helium. (Second Communication). By Prof. J. C. McLennan, F.R.S.C., and Mr. G. M. Shrum, M.A.

22.—On the Structure of the Wave length $\lambda = 6708$ Å.U. of the Isotopes of Lithium. By Prof. J. C. McLennan, F.R.S.C., and Mr. D. S. Ainslie, M.A.

23.—On the Absorption of the Wave length $\lambda = 5461$ Å.U. and of its satellites by ionised mercury vapour. By Prof. J. C. McLennan, F.R.S.C., and Mr. D. S. Ainslie, M.A., and Miss F. M. Cale, B.A.

24.—On the Prism Method of Determining the Refractive Indices of Metallic Vapours. By Mr. H. Grayson Smith, B.A. Presented by Prof. J. C. McLennan, F.R.S.C.

25.—On the Photography of Infra Red Spectra. By Mr. V. P. Lubovich, and Miss E. M. Pearen, B.A. Presented by Prof. J. C. McLennan, F.R.S.C.

26.—On the Application of the Theory of Magnetism to the Calculation of Atomic Diameters. By Mr. J. F. T. Young, M.A. Presented by Prof. J. C. McLennan, F.R.S.C.

27.—The Destruction by Ultraviolet Light of the Fluorescing Power of Dilute Solutions of Aesculin. By Miss F. M. Cale, B.A. Presented by Prof. J. C. McLennan, F.R.S.C.

28.—On the Photoelectric Conductivity of Diamond and other Phosphorescent Crystals. By Miss M. Levi, B.A. Presented by Prof. J. C. McLennan, F.R.S.C.

29.—On the Absorption Spectrum of Argon. By W. W. Shaver, M.A. Presented by Prof. J. C. McLennan, F.R.S.C.

30.—On the Low Voltage Arc Spectrum of Argon. By W. W. Shaver, M.A. Presented by Prof. J. C. McLennan, F.R.S.C.

31.—Asymptotic Planetoids. By Daniel Buchanan, F.R.S.C.

32.—On Surface Tension. By John Satterly, F.R.S.C.

33.—The Crooke's Radiometer as a Measuring Instrument. By John Satterly, F.R.S.C.

34.—Light Scattering by Dust-free Liquids. By W. H. Martin, M.A. Presented by Prof. F. B. Kenrick, F.R.S.C.

35.—On the Theory of Dispersion and Scattering of Light in Liquids. By Louis V. King, D.Sc., F.R.S.C.

36.—On the Electrical and Mechanical Characteristics of a New High Frequency Vibration Galvanometer. By Louis V. King, D.Sc., F.R.S.C.

37.—On the Numerical Computation of Elliptic Functions by Louis V. King, D.Sc., F.R.S.C.

38.—The Anemometer. By J. Patterson, F.R.S.C.

39.—Interferometer Paths of Unsymmetrical Dispersion. By Prof. H. F. Dawes, M.A., Ph.D. Presented by J. Patterson, F.R.S.C.

40.—A Method of Detecting Electrical and Magnetic Disturbances. By Brother Philip, B.A., F.S.C. Presented by J. Patterson, F.R.S.C.

41.—On the Depression of the Centre of a Thin Circular Disc of Steel under Normal Pressure. By Stanley Smith, M.A., B.Sc. Presented by Prof. R. W. Boyle, F.R.S.C.

42.—On the Electrical Conductivity of Animal Membranes. By H. E. Reilley. Presented by A. S. Eve, D.Sc., F.R.S.C.

43.—A Note on Missing Spectra. By A. S. Eve, D.Sc., F.R.S.C.

44.—The Softening of Secondary X-rays. By J. A. Gray, D.Sc., F.R.S.C.

45.—The Effective Range of the β-rays on Radium E. By Miss A. V. Douglas. Presented by J. A. Gray, F.R.S.C.

46.—The Reduction of Iron Ores by Carbon Monoxide. By Alfred Stansfield, D.Sc., F.R.S.C., and Donald R. Harrison, B.Sc.

47.—The Relative Influence of Radiation and Convection in Still or in Moving Air on the Change of Temperature of a Body in a Given Situation. By L. H. Nichols, B.A. Presented by A. S. Eve, D.Sc., F.R.S.C.

48.—A Note on the Comparison of Some Formulae for the Prediction of Estuary Tides. By A. N. Shaw, D.Sc. Presented by A. S. Eve, D.Sc., F.R.S.C.

49.—A Simple Method of Constructing Models for Demonstrating the Structure of Organic Crystals. By A. N. Shaw, D.Sc. Presented by A. S. Eve, D.Sc., F.R.S.C.

50.—Liquid Chlorine as an Ionizing Solvent. By John H. Mennie and D. McIntosh. Presented by Dr. F. M. G. Johnson, F.R.S.C.

51.—High Frequency Vibrations and Elastic Modulus of Metal Bars. By R. J. Lang, M.A. Presented by R. W. Boyle, F.R.S.C.

52.—Compressional Waves in Metals Produced by Impact. By R. W. Boyle, F.R.S.C.

53.—Cavitation in the Propagation of Sound. By R. W. Boyle, F.R.S.C.

54.—The Function of Resonance as a Part of the Physical Theory of Audition. By Frank Allen, F.R.S.C., and Miss M. Weinberg, M.A.

55.—Dissociation of Hydrogen by Electron Impacts. By A. Ll. Hughes, F.R.S.C.

56.—The Electrodeless Discharge in Diatomic Gases. By Prof. J. K. Robertson, M.A. Presented by A. L. Clark, Ph.D., F.R.S.C.

57.—The Manufacture of Cyanogen Compounds in Canada. By Horace Freeman. Presented by Dr. R. F. Ruttan, F.R.S.C.

58.—The Most Massive Star Known. By J. S. Plaskett, D.Sc., F.R.S.C.

59.—Criticisms of Saha's Ionization Hypothesis. By H. H. Plaskett. Presented by J. S. Plaskett, D.Sc., F.R.S.C.

60.—A Centrifuge Test of the Coagulating Power of an Electrolyte for Colloidal Solutions. By E. F. Burton, Ph.D., F.R.S.C., and J. E. Currie, B.A.

61.—The Variation in Mobilities of Ions and Colloidal Particles with the Viscosity of the Medium. By E. F. Burton, Ph.D., F.R.S.C., and J. E. Currie, B.A.

62.—The Mechanism of Catalysis by Nickel and by Platinum. By Maitland C. Boswell, F.R.S.C., and R. C. Cantelo.

63.—The Constitution of Rubber. By Maitland C. Boswell, F.R.S.C., and R. C. Cantelo.

64.—The Effect of Visual Reflex Action on the Sensation of Colour. By Frank Allen.

65.—The Variation of the Refractive Index of Oxygen with Pressure and the Absorption of Light by Oxygen at High Pressures. By Miss H. I. Eadie and Professor John Satterly. Presented by Prof. McLennan, F.R.S.C.

On motion of Mr. Patterson, seconded by Dr. Shutt, the report of Section III was adopted.

REPORT OF SECTION IV

During the three days of the Annual Meeting, May 17, 18 and 19, four sessions of Section IV were held and were attended by the following Fellows, 17 in number:—

Dr. W. A. Parks, President; Dr. F. D. Adams, Dr. C. Camsell, Dr. A. P. Coleman, Dr. W. H. Collins, Dr. D. B. Dowling, Mr. J. A. Dresser, Dr. E. R. Faribault, Mr. W. A. Johnston, Dr. E. M. Kindle, Dr. C. W. Knight, Mr. R. McConnell, Dr. W. McInnes, Dr. T. L. Walker, Dr. R. C. Wallace, Mr. J. White and Dr. G. A. Young, Secretary.

Three new Fellows were elected during the past year: Dr. John A. Allan, Mr. W. A. Johnston and Dr. S. J. Schofield.

The following resolutions were adopted:—

1. That the three vacancies now existing in the Section be filled.

2. That the necessary action be taken to secure permission to increase the membership of the Section by ten.

3. That the Printing Committee of the Section consist of three members to be elected and, in addition, the Secretary, who shall act as chairman.

4. The following resolution prepared by a Special Committee appointed to consider the general question of the publications of the Society:—

(*a*) That the papers presented each year before Section IV, and afterwards selected for publication by the Publications Committee of the Section, be published as a separate volume of the Transactions of the Society. It is thought that this procedure will accelerate the publication of papers, and that the resultant more complete segregation of papers upon closely related subjects will prove to be advantageous to readers of the Transactions.

(*b*) That the Secretary of the Section be advised to notify contributors of papers, after presentation of these papers, that the complete manuscripts must be delivered to the Secretary not later than June 30th. if publication is desired. Further, that papers selected for publication in the Transactions should be arranged consecutively in the order of priority of their receipt by the Secretary.

(*c*) In addition to the above recommendations to the general assembly it is recommended to this Section that further encouragement be given to the presentation of papers that deal with large problems and that are likely to promote collective study of such problems.

5. That Section IV is of the opinion, considering both the interests of members of the Section engaged in University work and those engaged in geological field work, that dates for the Annual Meeting, such as those chosen for the present year, are much more convenient than any dates subsequent to May 24th.

6. That the proposed changes in Section 8 relating to Duties of Members are considered by Section IV to be unnecessary and not in the best interests of the Society, and Section IV confirms the resolution

presented by the Section at the last annual meeting as still expressing their views in this matter.

7. The Royal Society of Canada has learnt with regret that the Government of Canada proposes to send only one representative to the International Geological Congress Meeting in August in Belgium. The Society is of the opinion that at least two representatives chosen from the Department of Mines should be sent to the Congress and authorizes Dr. F. D. Adams, Dr. A. P. Coleman and Mr. J. D. Dresser as representing the Society, to present this view of the matter to the Honourable Charles Stewart, Minister of Mines, and urge that the Government reconsider its decision.

8. That the following members of Section IV, namely, Frank D. Adams, Henry M. Ami, Reginald W. Brock, Charles Camsell, A. P. Coleman, Willet G. Miller, William Arthur Parks and Thomas L. Walker, be appointed members of a delegation from the Royal Society of Canada to the session of the International Geological Congress to be held in August of this year in Belgium, and that the Honorary Secretary be empowered to add to the numbers of this delegation any other members of Section IV who may signify their intention of attending the same session of this Congress.

The following were elected officers of the Section for 1922-3: President, Dr. E. R. Faribault; Vice-President, Dr. W. H. Collins; Secretary, Dr. G. A. Young.

The following are Committees appointed by the Section: Committee on Nominations, Mr. R. A. A. Johnston (1 year); Dr. William McInnes (2 years).

Committee on Printing: Dr. W. H. Collins, Dr. E. M. Kindle, Mr. R. A. A. Johnston.

Dr. W. H. Collins and Dr. G. A. Young were nominated to act on the General Printing Committee.

Dr. R. C. Wallace was appointed representative to the Committee created to act in the matter of the Sales Tax as it affects importations of foreign publications.

The following 17 papers were read either in full, by summary or by title:—

1. Presidential Address. W. A. Parks, Ph.D., F.R.S.C. The Development of Stratigraphy and Palaeontology in Canada.

2. Sedimentation in McKay Lake, Ottawa. By E. J. Whittaker, M.A., Geological Survey, Canada. Presented by Edward M. Kindle, A.B., M.Sc., Ph.D., F.R.S.C.

3. Some Outliers of the Monteregian Hills. By W. V. Howard, McGill University. Presented by Frank D. Adams, Ph.D., D.Sc., F.R.S., F.G.S., F.R.S.C.

4. Pleistocene Interglacial Deposits in the Vancouver Region, British Columbia. By Edward W. Berry, Johns Hopkins University, and W. A. Johnston, M.A., B.Sc., F.R.S.C.

5. The Historical and Structural Geology of the Southernmost Rocky Mountains of Canada. By J. D. MacKenzie, Ph.D., Geological Survey, Canada. Presented by W. H. Collins, B.A., Ph.D., F.R.S.C.

6.—Secondary Processes in some pre-Cambrian Ore-bodies. By R. C. Wallace, M.A., Ph.D., D.Sc., F.G.S., F.R.S.C.

7.—The Eastern Belt of the Canadian Cordilleras, An Enquiry into the Age of the Deformation. By D. B. Dowling. D.Sc., F.R.S.C.

8.—The Blithfield Meteorite. By R. A. A. Johnston, F.R.S.C., and M. F. Connor, B.Sc.

9.—Description of a Characeous Alga and of Two New Shield-bearing Arthropods from the Coal Measures of Nova Scotia. By W. A. Bell, B.Sc., Ph.D., Geological Survey, Canada. Presented by Edward M. Kindle, A.B., M.Sc., Ph.D., F.R.S.C.

10.—The Distribution of Zeolites in the Nova Scotian Basalts and its Significance. By T. L. Walker, M.A., Ph.D., F.R.S.C.

11.—Heulandite and Stilbite from Nova Scotia. By A. L. Parsons, B.A., Toronto University. Presented by T. L. Walker, M.A., Ph.D., F.R.S.C.

12.—Tubular Amygdaloid from Nova Scotia. By T. L. Walker, M.A., Ph.D., F.R.S.C.

13.—Parasaurolophus Walkeri, a new Genus of Crested Trachodont Dinosaur. By W. A. Parks, B.A., Ph.D., F.R.S.C.

14.—The Southern Extension of the Franklin Mountains. By Merton Yarwood Williams, B.Sc., Ph.D., F.G.S.A., University of British Columbia. Presented by R. W. Brock, M.A., LL.D., F.G.S., F.G.S.A., F.R.S.C.

15.—The Early Eocene Uplift of the Cretaceous Peneplain in the Southern Interior of British Columbia and the Development of the North Thompson Trench. By W. L. Uglow, M.A., M.S., Ph.D., University of British Columbia. Presented by R. W. Brock, M.A., LL.D., F.G.S., F.G.S.A., F.R.S.C.

16.—The Coast Range. By Stuart J. Schofield, M.A., B.Sc., Ph.D., F.G.S.A., F.R.S.A.

17.—On the Mispec Group (No. 2). By G. F. Matthew, LL.D., F.R.S.C.

G. A. Young,
Secretary, Section IV.

On motion of Dr. Young, seconded by Dr. Parks, the report of Section IV was adopted.

REPORT OF SECTION V

The Section held four sessions under the chairmanship of Prof. F. E. Lloyd. Twenty-three Fellows were present:—

A. H. R. Buller	A. G. Huntsman	P. S. McKibben
A. T. Cameron	A. P. Knight	J. P. McMurrich
J. H. Faull	F. J. Lewis	E. E. Prince
C. McL. Fraser	F. E. Lloyd	C. E. Saunders
Arthur Gibson	Jas. Miller	W. P. Thompson
V. J. Harding	C. L. Moore	R. B. Thomson
F. Harrison	A. B. Macallum	Arthur Willey
C. V.-A. Huard	A. H. Mackay	
A. Hunter	J. J. R. Macleod	

On the motion of Dr. Knight, seconded by Dr. Mackay, the chairman, Prof. F. E. Lloyd, was elected a member of the General Nominating Committee, the Secretary being the other representative of the Section.

Dr. A. G. Huntsman and Prof. F. E. Lloyd were appointed Editor and Associate Editor for the Section, and were named as the Section's representatives on the General Printing Committee.

The Section's appointees for the selection of the new Fellows are Dr. Willey and Prof. Lloyd.

The six new Fellows appointed this year bring the active membership up to thirty-seven. They are: Mr. Arthur Gibson (Ottawa), Dr. V. J. Harding (Toronto), Prof. F. R. Miller (London), Dr. James Miller (Kingston), Dr. C. H. O'Donoghue (Winnipeg), Dr. John Tait (Montreal).

At the request of the Honorary Secretary the Section took action in connection with the retirement of one of its formerly most active members. By unanimous vote it was decided to request that the name of Dr. T. J. W. Burgess be retained on the Honorary Retired List.

This action left the active membership of the Section at thirty-six. And in view of the large number of desirable candidates it was decided to ask the Council to allow the Section to fill the four remaining vacancies next year.

The Publication Committee's Report was approved by the Section and presented at one of the General Sessions. Its recommendations are as follows:—

1. (*a*) At the final session of the Council at the Annual Meeting the editorial committee of each Section shall be informed of the number of pages and plates to be allotted to that section in the Transactions, or the amount of money available for the same.

(*b*) Acting on this information the sectional editorial committee shall, immediately after June 15th, make a choice of the papers to be published and forthwith transmit these directly to the printer.

(*c*) In conformity with the rules as to type-setting, etc., the papers shall be immediately set up and proofs sent directly to the authors, with instructions that these must be returned at once. The author's reprints—both those furnished gratis and the additional copies ordered by each author—shall then be run off and sent to him.

(*d*) No paper received after June 15th shall be published in the Transactions for the current year.

(*e*) In 1923 and subsequent years, throughout the above clauses, read for "June 15th," "the last day of the General Meeting."

2. For convenience and expedition in editing, for library classification, and to save expense, the Transactions shall be published in two volumes, each bound in paper covers. These volumes shall consist respectively of: (*a*) the papers of Sections I and II, and (*b*) the papers of Sections III, IV and V.

It is further the opinion of your sub-committee that if prompt publication can be secured (as it is believed would occur if the above recommendations be adopted) many of the scientific papers which are at present published in the journals of other countries would be submitted for publication in the Transactions of the Royal Society, and from this might develop a means of more frequent publication and an increase in the scope and usefulness of the Society's work.

The sub-committee further recommend to the Section that:—

The sectional editorial committee shall consist of an editor, together with an associate editor, who shall be appointed from among the fellows who, in virtue of their own work, are known to be interested in the prompt publication of the Transactions, and that the editor report at the Annual Meeting.

The following additional resolutions were passed on to the General Meeting:—

1. That the Section favours the adoption of the amendment to Section VIII, of the By-laws prepared by Section III, with the following change and addition:—

(*a*) In the last sentence after "Annual Meetings," in place of "shall" read "may."

(*b*) At the end add "Otherwise his name shall be removed from the list of members by the Honorary Secretary."

The By-law then reads as follows:—

(1) Each member shall submit at the Annual Meeting after his election or at either of the two next Annual Meetings a paper embodying the results of original research carried out by himself, or an original paper upon some subject pertaining to the work of the Section of which he is a member, and shall continue to submit such papers at least once in three years or attend the Annual Meeting at least once in three years.

Any member who fails to comply with the requirements of this section of the By-laws with regard to the presentation of papers or attendance at Annual Meetings may, on recommendation of the Section, be placed on the retired list by the Honorary Secretary. Otherwise, his name shall be removed from the list of members by the Honorary Secretary.

(2) That owing to the difficulty experienced by Fellows resident at distant points in attending the meeting when fixed for an early date it is resolved that the Annual Meeting be held at a date not earlier than the 24th of May.

(3) That the Society be requested to defray in part (as for Fellows at the Annual Meeting) the travelling expenses of the members of the Council and of such committees as are required by the By-laws of the Society to meet between successive Annual Meetings.

(4) That on the occasion of the retirement from the government service of Dr. C. E. Saunders, the Society desires to express its appreciation of the work accomplished by Dr. Saunders in having developed new varieties of cereals, and in particular "Marquis Wheat," and at the same time the Society deplores the existing conditions in the Civil Service that render his retirement and loss to Canada necessary, and that the Honorary Secretary be instructed to forward a copy of this resolution to each of the members of the Dominion Cabinet.

The officers elected for the coming year are as follows: Chairman, Dr. Arthur Willey; Vice-Chairman, Dr. Andrew Hunter; Secretary, R. B. Thomson.

The following papers were read in full or by abstract at the sessions of the Section:—

1.—Presidential Address. The Occurrence and Functions of Tannin in the Living Cell. By Francis E. Lloyd, M.A., F.R.S.C.

2.—New Canadian Entomostraca (Copepoda). By A. Willey, D.Sc., F.R.S., F.R.S.C. (Lantern).

3.—(i) Rusty Herring. By F. C. Harrison, B.S.A., D.Sc., F.R.S.C.

4.—(ii) The Red Discolouration of Cured Codfish. By Francis C. Harrison, D.Sc., F.R.S.C., and Miss Margaret Kennedy.

5.—Marine Spore-Forming Bacteria. By Dorothy E. Newton, B.S.A. Presented by F. C. Harrison, B.S.A., D.Sc., F.R.S.C.

6.—Some Observatiuns on the Inheritance of Awns and Hoods in Barley. By Charles E. Saunders, Ph.D., LL.D., F.R.S.C., assisted by G. G. Moe, B.S.A., M.S. (Lantern).

7.—(i) Ichthyological Notes. By C. McLean Fraser, M.A., Ph.D., F.R.S.C.

8.—(ii) The Embryology of the Chum Salmon *Oncorynchus Keta* (Walbaum). By H. A. Dunlop, B.A. Presented by C. McLean Fraser, M.A., Ph.D., F.R.S.C.

9.—(i) Mutations in Cereals. By W. P. Thompson, M.A., Ph.D., F.R.S.C. (Lantern).

10.—(ii) A Dwarf Form of Marquis Wheat which is not Viable in the Homozygous Condition. By W. P. Thompson, M.A., Ph.D., F.R.S.C. (Lantern).

11.—(iii) Biologic Forms of Wheat Stem Rust in Western Canada. By Miss Margaret Newton, M.A. Presented by W. P. Thompson, M.A., Ph.D., F.R.S.C.

12.—(iv) The Evolution of the Angiospermic Vessel. By W P. Thompson, M.A., Ph.D., F.R.S.C. (Lantern).

13.—(i) The Bioluminescence of *Panus stypticus*. By A. H. Reginald Buller, D.Sc., Ph.D., F.R.S.C. (Lantern).

14.—(ii) Hyphal Fusions and Social Organization in *Coprinus sterquilinus* and Other Fungi. By A. H. Reginald Buller, D.Sc., Ph.D., F.R.S.C. (Lantern).

15.—(iii) Homothallism and Heterothallism in the Genus Coprinus. By Irene Mounce, M.A. Presented by A. H. Reginald Buller, D.Sc., Ph.D., F.R.S.C. (Lantern).

16.—Studies on Experimental Diabetes. By F. G. Banting, C. H. Best, J. B. Collip, J. Hepburn, J. J. R. Macleod and E. C. Noble.

17.—(i) The Bog-Forests of Lake Memphremagog, their Destruction and Consequent Successions in Relation to Water Levels. By Francis E. Lloyd, M.A., F.R.S.C., and George W. Scarth, M.A.

18.—(ii) River-Bank and Beach Vegetation of the St. Lawrence River below Montreal in Relation to Water-Levels. By Francis E. Lloyd, M.A., F.R.S.C., and George W. Scarth, M.A.

19.—(iii) Study of Induced Changes in form of the Chloroplasts of Spirogyra and Mougeotia. By George W. Scarth, M.A. Presented by Francis E. Lloyd, M.A., F.R.S.C.

20.—Acceleration of Growth and Regression of Organ-Hypertrophy in Young Rats after Cessation of Thyroid Feeding. By A. T. Cameron, M.A., B.Sc., F.I.C., F.R.S.C.

21.—A Preliminary Report on the Limnology of Lake Nipigon. By Wilbert A. Clemens, M.A., Ph.D. Presented by B. A. Bensley, B.A., Ph.D., F.R.S.C.

22.—(i) The Progress of Tryptic Digestion of Protein as Studied by the Method of Butyl Alcohol Extraction. By Andrew Hunter, M.A., B.Sc., F.R.S.C.

23.—(ii) The Action of Trypsin upon the Amide Nitrogen of Proteins. By Andrew Hunter, M.A., B.Sc., F.R.S.C.

24.—(iii) A Study of the Action of Arginase. By Andrew Hunter, M.A., B.Sc., F.R.S.C., and J. A. Morrell, B.A.

25.—(iv) The Question of the Presence of the Tryptophane Radicle in Hemoglobin. By Andrew Hunter, M.A., B.Sc., F.R.S.C., and H. Borsook, B.A.

26.—(i) The Ascidian Family Cæsiridæ. By A. G. Huntsman, B.A., M.B., F.R.S.C.

27.—(ii) The Genera of Simple Ascidians of Savigny and Fleming, with Remarks on Nomenclature. By A. G. Huntsman, B.A., F.R.S.C.

28.—The Employment of a Quantitative Method in the Study of the (so-called) d'Herelle Phenomenon. By H. B. Maitland, M.B. M.R.C.S. Presented by J. J. MacKenzie, B.A., M.B., F.R.S.C.

29.—(i) The Excretion of Creatine and Creatinine in Childhood and Disease. By V. J. Harding, D.Sc., F.R.S.C., and O. H. Gaebler.

30.—(ii) The Excretion of Acetone Bodies and Nitrogen in the Treatment of Nausea and Vomiting of Pregnancy. By V. J. Harding, D.Sc., F.R.S.C., and C. T. Potter.

31.—(i) Two Undescribed Butt Rots of Conifers. By J. H. Faull, B.A., Ph.D., F.R.S.C. (Lantern).

32.—(ii) A New Peridermium on *Abies balsamea* and a new Uredinopsis on the Common Polypody. By Hugh P. Bell, M.Sc. Presented by J. H. Faull, B.A., Ph.D., F.R.S.C. (Lantern).

33.—(i) A Hybrid between Picea and Abies. By Robert Boyd Thomson, B.A., F.R.S.C. (Lantern).

34.—(ii) The Primordial Pit and Bar of Sanio in the Gymnosperms. By H. B. Sifton, M.A. Presented by Robert Boyd Thomson, B.A., F.R.S.C. (Lantern).

35.—(i) Observations in the Deposition of Bone Salts. By J. C. Watt, M.A., M.D. Presented by J. Playfair McMurrich, M.A., Ph.D., F.R.S.C.

36.—(ii) The Terminal Branches of an Emphysematous Lung. By H. G. Willson, M.A., M.D. Presented by J. Playfair McMurrich, M.A., Ph.D., F.R.S.C.

37.—A Case of Gynandromorphism in *Gallus domesticus*. By Madge T. Macklin, B.S., M.D. Presented by Paul S. McKibben, Ph.D., F.R.S.C.

On motion of Professor Thomson, seconded by Dr. Buller, the report of Section V was adopted.

The meeting again took into discussion the proposed amendment to By-law No. 8. Resolutions were presented by a representative of each of the Sections. These resolutions showed a wide diversion of opinion, and after considerable discussion it was moved by Dr. Wallace, seconded by Mr. Burpee, that the matter be referred to the Council, the suggestions of each of the Sections as embodied in their respective resolutions to be taken into consideration, and Council to report, at the next annual meeting.

Dr. Huntsman then read a report of the sub-committee of Section V on the manner of publication of papers. Discussion ensued, and it was finally moved by Dr. Huntsman, and seconded by Prof. Thomson, that the recommendation contained in Section I of the report be adopted. Section I read as follows:—

1. (*a*) At the final session of the Council at the Annual Meeting the editorial committee of each section shall be informed of the number of pages and plates to be allotted to that section in the Transactions, or the amount of money available for the same.

(*b*) Acting on this information the sectional editorial committee shall, immediately after June 15th, make a choice of the papers to be published and forthwith transmit these directly to the printer.

(*c*) In conformity with the rules as to type-setting, etc., the papers shall be immediately set up and proofs sent directly to the authors, with instructions that these must be returned at once. The author's reprints—both those furnished gratis and the additional copies ordered by each author—shall then be run off and sent to him.

(*d*) No paper received after June 15th shall be published in the Transactions for the current year.

(*e*) In 1923 and subsequent years, throughout the above clauses read for "June 15th," "the last day of the General Meeting."

The motion was then agreed to.

The Society next considered the date of the Annual Meeting. After some discussion the suggestion was offered that the Honorary Secretary should send out a questionnaire with a view to ascertaining the opinion of the individual Fellows as to the most suitable date for holding the Annual Meetings.

The report of the Committee appointed to interview the Minister of Mines regarding additional representation at the International Congress of Geologists next August was then presented as follows:—

> Your Committee appointed to interview the Minister of Mines and convey to him the request of the Royal Society of Canada that at least two representatives should be sent by the Government of Canada to the International Congress of Geologists to be held in Brussels next August beg to report that they interviewed the Hon. Mr. Stewart this afternoon and advocated that such action should be taken. Mr. Stewart received the deputation cordially and will give the matter his attention at once.
>
> FRANK D. ADAMS. JOHN A. DRESSER.

Professor Lloyd offered the suggestion that the Council should hold meetings during the progress of the Annual Meeting, which the incoming Council was asked to take into consideration.

Dr. J. Playfair McMurrich then presented the report of the committee appointed by the President on plans for the organization of a National Museum. This committee consisted of the following: Dr. Camsell, Dr. Currelly, Mr. Gibson, Dr. Huntsman, Mr. R. A. A. Johnston, Professor Lloyd, Dr. McInnes, Dr. Sapir and Dr. McMurrich, chairman. The report was as follows:—

> Your Committee begs to report that at a meeting held May 17th preliminary arrangements were made for a careful study of the problems concerned and at the present time would merely report progress and request that it be continued.
>
> J. PLAYFAIR MCMURRICH, *Chairman.*

The report of the Nominating Committee was presented by Dr. A. S. Eve, and the following nominations were made:—

1.—President, Dr. J. Playfair McMurrich.

2.—Vice-President, Hon. Thomas Chapais.

3.—Honorary-Secretary, Dr. Charles Camsell.

4.—Honorary-Treasurer, Dr. C. M. Barbeau.

5.—Honorary Librarian, Dr. D. B. Dowling.

It was moved by Dr. Eve, seconded by Dr. Coyne, that this report be accepted.—Carried.

In the absence of both the newly-elected President and Vice-President Dr. Scott remained in the chair.

It was moved by Mr. Burpee, seconded by Judge Howay, that the following Fellows constitute the general printing committee for the year: Mr. Barbeau, Mr. Gerin, Dr. Scott, Dr. Shortt, Mr. Bain, Mr. Patterson, Dr. Collins, Dr. Young, Dr. Huntsman and Professor Lloyd.

It was moved by Mr. Burpee, seconded by Professor Prince, that Dr. Shortt and Dr. Glashan be appointed auditors for the year 1922-23.—Carried.

It was moved by Dr. Bryce, seconded by Professor Hill-Tout, that the thanks of the Society be presented to the Deputy Minister of Mines and to Dr. McInnes, the Director of the Victoria Memorial Museum, for their kindness in arranging for the accommodation for the Annual Meeting.—Carried.

It was moved by Mr. Gibson, seconded by Dr. C. McLean Fraser, that the thanks of this meeting be presented to the officers of the Society, the Members of Council, and the Auditors, for their very efficient services during the past year.—Carried.

It was moved by Mr. Burpee, seconded by Dr. Dowling, that the thanks of the Society be extended to the Press of Ottawa for their admirable reports of the meetings.

The meeting was then declared adjourned.

APPENDIX A

PRESIDENTIAL ADDRESS

POETRY AND PROGRESS

BY

DUNCAN CAMPBELL SCOTT, Litt.D., F.R.S.C.

May 17, 1922

POETRY AND PROGRESS

I have the honour to deliver this evening the forty-first presidential address of the Royal Society of Canada. It is the custom of our Society that the presidency shall devolve in turn upon each of our Sections, and the Section of English Literature last year claimed the privilege of nominating the president of the Society.

I have thought to speak on this occasion of ideals and progress: first, and briefly, on the ideals of the Society,—those who formed it and gave it body and constitution, and then, in a more discursive fashion, about ideals in poetry and the literary life, and their relation to progress. There is, I claim, something unique in the constitution of a society that comprises Literature and Science, that makes room for the Mathematician and the Chemist, the Historian and the Biologist, the Poet and the Astronomer. Every intellectual type can be accommodated under the cloak of our charter, and we have survived forty-one years of varied activity with a degree of harmony and a persistence of effort towards the end and purpose of our creation that is worthy of comment. We are unique also in this, that two languages have equal recognition and *authority* in our literature sections, and that the premier place is occupied by the first civilized language heard by the natives of this country, which is ever the pioneer language of ideals in freedom and beauty and in the realm of clear logic, criticism and daring speculation. It here represents not a division of race, but a union of nationality, and joins the company of intellectuals by the dual interests of the two great sections of our people. We find our scientific sections welcoming essays in the French language and our literary sections interchanging papers and holding joint sessions on folk-lore and history. The ideal which possessed the founder of this Society and its charter members was undoubtedly that such an organism could live and flourish, that it could become a useful institution in Canadian life. We have progressively proved that, we prove it to-night, and we shall, I am confident, continue our demonstration in the future. Is it too fanciful to think or say that the element of cohesion which made this possible is idealism, or that gift of ideality which all workers who use Mind as an instrument possess in varying degree? The mental process by which a poet develops the germ of his poem and perfects it is analogous to the process by which a mathematician develops his problem from vagueness to a complete demonstration, or to the mental process whereby the shadow of truth apprehended by the biologist becomes proven fact. The scientist and mathematician may proceed in diverse ways to give scope to the creative imagination, and their methods are inherent in their problems. They proceed by experiment and by the logical faculty to a point of rest, of completion. The poet is unsatisfied until his idea is cleared of ambiguity and becomes embodied in a perfect form. The art of the poet is to clothe his idea with beauty and to state it in terms of loveliness, but the art of fine writing —style—need not be absent from the record of scientific achievement: it is, in fact, often present in marked degree. I doubt whether the satisfaction of the poet in finishing his work and perfecting it is essentially different or greater than the satisfaction of the scientist who rounds out his experiment and proves his theory. Such delights cannot be weighed or measured, but they are real and are enjoyed in common by all workers who seek perfection. I now boldly make the statement, which I at first put hesitatingly, in the form of a question, that it is ideality that holds our Society together, and that it was founded truly in the imagination of those who thought that such an institution could flourish in our national life.

During the past forty years many distinguished men have joined in this Fellowship—some have passed from this to greater honours, and others have passed away, but our methods of election and the keenness which our Fellows show in choosing their future colleagues ensure a steady stream of vigorous thought.

The subjects comprised in Section II, to which I have the honour to belong, are certainly varied,—English Literature, History, Archaeology, Sociology, Political Economy and allied subjects; and some of the allied subjects are most important, such as Philosophy and Psychology. While we have this wealth of subject matter, the scientific sections have an advantage over us in that they have greater solidarity of aim, that their groups have clearly-defined objects of study and investigation, and their results are more tangible. We must envy the scientists the excitement of the intellectual world in which they live. Consider for a moment the changes in scientific theory, method, and outlook since the charter members of this Society met together in 1882. It would not become me to endeavour to mention even the most important, but the realm of science appears to an outsider to be a wonderland. By comparison, literature seems to be divorced from life, and we would need to point to some book that had altered definitely the course of the world's thought to match some of the discoveries of Science which have changed our conceptions of the nature of life and of the universe. Perhaps, in making this remark, I am confusing for the moment the function of pure literature with the functions of Science. Literature in its purest form is vowed to the service of the imagination; its ethical powers are secondary, though important; and it cannot be forced to prove its utility. Literature engaged with the creation of beauty is ageless. The biological notions of Elizabeth's day are merely objects of curiosity, but Marlowe, Webster and Shakespeare are living forces. Sir Thomas Browne's medical knowledge is useless, but his "Urn Burial" is a wonder and a delight. Created, beauty persists; it has the eternal element in its composition, and seems to tell us more of the secret of the universe than philosophy or logic. But Letters will always envy Science its busyness with material things, and its glowing results which have rendered possible many of the imaginative excursions which poetry, for example, has made into the unknown.

It would be difficult, nay, impossible, to change radically the methods of pure literature working in the stuff of the imagination. New ideas can be absorbed, new analogies can be drawn, new imagery can be invented, but the age-old methods of artistic expression will never be superseded. Apart from pure literature, or Belles Lettres, those subjects allotted to our section which are capable of scientific treatment, History, for instance, show a remarkable development. The former story-telling function of History and the endless reweaving of that tissue of tradition which surrounded and obscured the life of a people has given place to a higher conception of the duty of the Historian and the obligation to accept no statement without the support of documentary evidence. The exploration and study of archives and the collation of original contemporaneous documents are now held to be essential, and the partisan historian fortified with bigotry and blind to all evidence uncongenial to his preconceptions is an extinct being. International effort and co-operation have taken the place of jealous sectionalism and the desire to unfold the truth has displaced the craze to prove a theory. The new Science of History has its material in archives and collections of original documents, and one must here refer to the growth of our own Dominion collections under the guidance of an Archivist who is one of us, and who is aided by other distinguished Fellows of the Society. It should be remarked that one of the objects set forth by our charter was to assist in the collection of archives and to aid in the formation of a National Museum of Ethnology, Archaeology and Natural History. Let us not weaken for a moment in the discharge of this obligation. The Archives and the Museum exist largely owing to the influence of our Society, exerted constantly with great pressure, and, in times of necessity, with grave insistence. The Museum needs we consider highly important, and, as you are all aware, we intend to assist the

Government to come to wise conclusions in these matters, and to keep alive and vigorous all projects that aim at conserving and developing our intellectual resources.

We talk too often and too lengthily about Canadian poetry and Canadian literature as if it was, or ought to be, a special and peculiar brand, but it is simply poetry, or not poetry; literature or not literature; it must be judged by established standards, and cannot escape criticism by special pleading. A critic may accompany his blame or praise by describing the difficulties of the Canadian literary life, but that cannot be allowed to prejudice our claim to be members of the general guild. We must insist upon it. If there be criticism by our countrymen, all that we ask is that it should be informed and able criticism, and that it too should be judged by universal standards. Future critics will recognize the difficulties which oppress all artistic effort in new countries, as do the best of contemporary critics. As Matthew Arnold wrote, in countries and times of splendid poetical achievement: "The poet lived in a current of ideas in the highest degree animating and nourishing to the creative power; society was, in the fullest measure, permeated by fresh thought, intelligent and alive; and this state of things is the true basis for the creative power's exercise". When we seek in our contemporary society for the full permeation of fresh thought, intelligent and alive, we do not find it; we do not find it in America or elsewhere, and if the premise is sound we can say, therefore, we do not find an ample and glorious stream of creative power. It is casual, intermittent, fragmentary, because society is in like state. But we may be thankful that in our country there has been and is now a body of thought, intelligent and alive, that gives tangible support to the artist and that has assisted him in his creative work.

You will note that I am taking high ground, in fact, the highest, in dealing with literature and the highest form of literature—poetry. I am well aware that there is a great increase in our written word during the last twenty-five years, and our writers are now competently meeting the varied demand of readers whose taste does not require anything too finely wrought nor too greatly imagined. I heard one of our successful writers declare the other day that what we should do now is to get the "stuff" down somehow or other and never to mind how it was done so long as it was done. Well, that would give us all the rewards of haste, but would hardly assist in building a literature. There must ever be this contrast between the worker for instant results and the worker who toils for the last perfection. One class is not without honour, the other is precious beyond valuation. As time passes we shall find in this country, no doubt, a growing corpus of stimulating thought that will still more tend to the nourishing and support of creative genius.

While we do not wish to part Canadian Literature from the main body of Literature written in English, we may lay claim to the possession of something unique in the Canadian literary life,—that may be distinguishable to even casual perception by a peculiar blend of courage and discouragement. In truth, there is such lack of the concentration that makes for the drama of literary life that it is almost non-existent. But, nevertheless, our resident authors, those who have not attempted to escape from this environment, have done and are doing important work in imaginative literature. I have thought to touch briefly upon two such lives typical of the struggle for self-expression in a new country.

If there had existed in our Society a rule that is observed in the French Academy, it would have been my duty to have pronounced, upon taking my chair, a eulogy on Archibald Lampman, who had died the year previous to my election, and to whose chair I succeeded. I would hardly have been as competent then to speak of him and his work as I am now, for both were too near to me then, and now I have the advantage of added experience, and, after a lapse of twenty odd years, poetic values shift. But what is poetic truth does not change, and it is a high satisfaction to find that there was so much of poetic truth in the work of my friend, our colleague, truth that fortifies, and beauty that sweetens life. He felt the oppression of the dullness of the life about us more keenly than I did, for he had fewer channels of escape, and his responsibilities were heavier; he had little if any enjoyment in the task-round of every day, and however much we miss the sense of tedium in his best work, most assuredly it was with him present in the days of his week and the weeks of his year. He had real capacity for gaiety and for the width and atmosphere of a varied and complex life, not as an actor in it perhaps, but as a keen observer, and as a drifter upon its surface, one in whom the colour and movement of life would have created many beautiful and enchanting forms. But he was compelled to work without that stimulus, in a dull environment and the absence also of any feeling of nationality, a strong aid and incitement to a poet, no matter how much we may talk nowadays about the danger of national feeling. This lack made sterile a broad tract of his mind; it was a discouragement that he could not know that he was interpreting the aspirations and ideals of a national life. We still feel that lack of national consciousness, but perhaps it is a trifle less evident now. His love of country was very strong and took form in his praise of nature, that unsoiled and untrammelled nature that we think of as Canada, and his work in this kind has a verity and vigour that is unmatched. He filled the rigid form of the sonnet with comments on the life of the fields and woods and waters that ring as true as the notes of birds. A single half-hundred of these sonnets of his may be placed in any poetic company and they will neither wilt nor tarnish. Towards the end of his life he chose by sympathy to write more imaginatively about stirrings in the mind and heart of man, and there is a deep and troubled note in these things that gave portent of a new development. His career was closed too soon, and we have but to cherish what is left and rejoice over it as a treasure of our literary inheritance.

It is twenty-three years since Lampman died, and the period is marked by the death of Marjorie Pickthall, which occurred during April of this year at Vancouver. Her's was a literary life of another and contrasted kind. She was of English parentage, born in England, but educated in Canada, and she was in training and sentiment a good Canadian.

If one were looking for evidence of progress in Canadian literature during the period of thirty years just referred to, one positive item would be the difference in the reception of the first books published by these two authors. Until the generous review by William Dean Howells of Lampman's book had been published in Harper's Magazine, it was here considered, when any consideration whatever was given to the subject, a matter of local importance. But the warm-hearted welcome of Howells led to sudden recognition of the fact that the book was an acquisition to general literature, and was not merely parochial. After that incident, and others like it, we find that recognition of Miss Pickthall's first book took place at once, and from our independent judgment, as an important addition to poetical literature. Advance is clearly shown by this fact; for until we have faith in the power of our writers we can have no literature worth speaking about; our position in arts and letters will be secured when we find foreign critics accepting a clear lead from us. We accepted Miss Pickthall, and our opinion was confirmed very generally afterwards.

It is to be deeply regretted that her career is closed and that we shall not again hear, or overhear, that strain of melody, so firm, so sure, floating towards us, to use a phrase of Lampman's, "as if from the closing door of another world and another lovelier mood." "Overhear" is, I think, the right word, for there was a tone of privacy, of seclusion, in her most individual poems, not the seclusion of a cloister, but the seclusion of a walled garden with an outlook towards the sea and the mountains. Life was beyond the garden somewhere, and murmurously, rumours of it came between the walls and caused longing and disquiet. The voice could be heard mingling the real appearance of the garden with the imagined forms of life beyond it and with remembrances from dim legends and from the untarnished old romances of the world. Her work was built on a ground bass of folk melody, and wreathed about it were Greek phrases and glamours from the "Song of Songs." But composite of all these influences, it was yet original and reached the heart with a wistfulness of comfort. She had a feeling for our little brothers of the air and the woods that was sometimes classical, sometimes mediaeval. Fauns and hamadryads peopled her moods, and our familiar birds and flowers took on quaint forms like the conventional shapes and mellow colours of tapestries woven long ago. "Bind above your breaking heart the echo of a Song"—that was her cadence, the peculiar touch that gives a feeling of loneliness and then heals it, and if one might have said to her any words at parting, they would have been her own words—"Take, ere yet you say good-bye, the love of all the earth".

These two lives are typical of the struggle of those who attempt the literary life in Canada. Lampman existed in the Civil Service, and was paid as any other clerk for the official work he did. Neither his position nor his advances in that position were given in recognition of his literary gifts. From this bleak vantage ground he sent out his version of the beauty of the world. Miss Pickthall was more definitely in the stream of letters, and her contributions to the periodical press in prose and verse gave her an assured standing and due rewards.

There is no necessity here and now for an apology for poetry nor for a defence of anyone who in Sir Philip Sydney's words "showeth himself a passionate lover of that unspeakable and everlasting beauty to be seen by the eyes of the mind". I admire that ideal, set up by the Welsh saying for the perfect man, the man who could "build a boat and sail it, tame a horse and ride it, make an ode and set it to music". None of us could qualify for perfection under this hard and inclusive test. It covers, you will observe, mastery of several kinds,—mastery of craftsmanship, and fearless daring; mastery of a difficult and most noble animal; and, finally, the crowning mastery of poetry and music. We find it true of all peoples that these two arts are the cap stones of their civilizations. We are as far as ever from an understanding of what poetry really is, although we are at one in giving it supremacy in the arts and we are as far as ever from a perfect definition of poetry. Perhaps the best, the only definition of poetry is a true poem, for poetry and the poetic is a quality or state of mind and cannot be described, it is apprehended by sensation, not comprehended by reason. This renders ineffectual all attempts to answer the question, "What is poetry?", and makes futile the approved definitions.

These efforts to define what is undefinable inevitably tend to become creative attempts, approximate to poetic utterance, and endeavour to capture the fugitive spirit of poetry by luring it with a semblance of itself. But the question is answered perfectly by even the fragment of a true poem. We know instinctively and say, "This is poetry", and the need for definition ceases.

The finest criticism of poetry plays about this central quality like lightning about a lovely statue in a midnight garden. The beauty is flashed upon the eye and withdrawn. It is remembered in darkness and is verified by the merest flutter or flash of illumination, but the secret of the beauty is shrouded in mystery. I refer to such sayings as this of Coleridge: "It is the blending of passion with order that constitutes perfection" in poetry; that of Keats, "The excellence of every art is its intensity"; that of Rossetti, "Moderation is the highest law of poetry". There are numerous like apothegms written by poets and critics about the art of poetry that accomplish perfectly the necessary separation between the art and the spirit of the art, between the means and the effect. They are flashed upon the mystery and isolate it so that it may be apprehended by its aloofness and separation from things and appearances. We can apply Coleridge's words to any chosen passage of Keats, for example, the familiar "magic casements opening on the foam of perilous seas in fairy lands forlorn". We acknowledge that the perfection of the passage lies in the romantic passion blended with the order that is the sense of balance and completion, but the poetic quality escapes, it is defined, by the effect of the passage and by that alone.

We quote the words that Shakespeare puts into Anthony's mouth—

"I am dying, Egypt, dying only of many thousand kisses the poor last I lay upon thy lips."

We recognize that the excellence of this passage comes from its intensity. And even such an outcry, poignant to the verge of agony, is not inconsistent with the saying of Rossetti; for moderation is a question of scale. The high law of moderation is followed in such an utterance of Anthony's as competently as when Hamlet says simply "The rest is silence", because it is true in the scale of emotion.

Of a truth the ideals of our contemporary poets are not those of the masters of the past,—neither their ideals of matter, of manner, of content or of form. Tennyson's thought "of one far off divine event to which the whole creation moves" is not only inadequate to express what a poet of the present day feels about the destiny of man and about the universe; it fails in appeal, it is merely uninteresting to him; and no modern poet would say as Matthew Arnold said: "Weary of myself, and sick of asking what I am and what I ought to be". Tennyson and Arnold are comparatively recent leaders of thought and we are more akin to the Elizabethans with their spirit of quest than we are to Wordsworth and Arnold. In our ideals of technique we are farther removed from the eighteenth century, from Pope and Gray, than from Donne and Herrick and Vaughan. Our blank verse at its best shuns all reference to Milton and has escaped once again into the freedom of Shakespeare and the wilderness of natural accent. The best of the work shows it, and from the mouths of the poets themselves we sometimes gather their perception of kinship with masters whose influence was unfelt by the Victorians. I remember well an observation Rupert Brooke made to me one evening during his visit to Ottawa in August, 1913, as we strolled over the golf links. There was a heavy dew on the grass, I remember,—one could feel it in the air, and the sky was crowded full of stars; the night, and peculiarly the coolness of the dew-saturated air recalled some line of Matthew Arnold. "How far away that seems", Brooke said, "far away from what we are trying to do now,—John Donne seems much nearer to us". It is the intensity of Donne that fascinated Brooke. It was that intensity that he was endeavouring to reach in his poem "The Blue Room", or in the stillness of arrested time portrayed in "Afternoon Tea". The diffuseness in Wordsworth and Arnold was the quality that made them remote. Brooke was fated for other things than to pursue the cult of intensity. Now we think of him as the interpreter of certain emotional states that arose from the war, and we may select Wilfred Owen as the exponent of certain other sharply hostile states.

The contrast between these typical natures is the contrast between the traditional feeling for glory and the personal feeling of loss and defeat to be laid to the national debit. Brooke identifies himself with the magnificence of all the endeavour that has gone to create national pride; his offering is one of joy, all is lost in the knowledge that he continues the tradition of sacrifice for the national ideal. Wilfred Owen feels only the desperate personal loss, loss of the sensation of high living, the denial by the present of the right of youth to the future. The contrast is known when we place Brooke's sonnet "Blow Out Ye Bugle Over the Rich Dead," beside Owen's, "Apologia". The first glows with a sort of mediaeval ecstasy, the second throbs with immediate sincerity and ironic truth. It is the voice of a tortured human soul. There has been agony before in English poetry, but none like unto this agony. How far removed is it from echoes of the drums and trumpets of old time valour, how far away from such a classic as "The Burial of Sir John Moore"? Here is an accent new to English poetry. There is the old power of courage, the indomitable spirit of the forlorn hope, but the anaesthetic of glory is absent, and the pain of all this futile sacrifice based on human error and perversity is suffered by the bare nerve without mitigation.

Rupert Brooke's admiration of that bare technique, fitted to that strange and candescent intellect of Donne's was forgotten when he touched those incomparable sonnets of his. In them the intensity of feeling takes on a breadth and movement which is an amalgam of many traditions in English poetry, traditions of the best with the informing sense of a new genius added, the genius of Rupert Brooke. In his case, as in the case of all careers prematurely closed, it is idle to speculate upon the future course of his genius. It may be said, however, that his prose criticism, his study of Webster and his letters show that his mind was philosophic and that his poetic faculty was firmly rooted in that subsoil and had no mere surface contact with life. Our faith that Keats would have developed had he lived, takes rise from our knowledge of the quality of his mind, as shown in his criticism and in his wonderful letters. We can say confidently that a poetic faculty based on such strong masculine foundation, with such breadth of sympathy, would have continued to produce poetry of the highest, informed with new beauty and with a constant reference to human life and aspirations. With due qualifications the same confidence may be felt in the potential power of Rupert Brooke. He had not Keats' exquisite gift, but he was even more a creature of his time, bathed in the current of youthful feeling that was freshening the life of those days, and he would have been able to lead that freshet of feeling into new and deep channels of expression. Close association for a week with so eager a mind served to create and enforce such opinions. He seemed, so far as his talk went, more interested in life than art, and there was a total absence of the kind of literary gossip that so often annoys. His loyalty to his friends and confreres was admirable, and he had greater pleasure in telling what they had done than in recounting his own achievements,—what their hopes were rather than his own. I remember his saying that he intended to write drama in the future and put himself to the supreme test in this form of art. One cannot think of his figure now except in the light of tragic events that were hidden then, when there was no shadow, only the eagerness of youth and the desire of life.

Wilfred Owen too, and others of his group, inherited that touch of intensity, but there was bitterness added and he had to bear the shock of actual war which Brooke did not experience,—the horrors of it and the futility. It is to be doubted whether such writers as Owen or Sorley could have assumed or continued a position in post war literature, whether they could have found subjects for the exercise of such mordant talents.

There was a tremendous activity of verse-writing during the war, and the hope was often expressed that there was to be a renaissance of poetry and our age was to be nobly expressed. But the war ceased; the multitude of war poets ceased to write; the artificial stimulus had departed and they one and all found themselves without a subject. Whatever technique they had acquired for the especial purpose of creating horror or pity was unfitted for less violent matter. The ideals which they had passionately upheld received the cold shoulder of disillusionment. The millennium had not arrived, in very truth it seemed farther off than ever, and the source of special inspiration had dried up. But the elimination of these poets of the moment did not affect the main development of poetry. Those poets, who had been in the stream of tendency, and who were diverted by the violent flood of war feelings and impressions settled back upon the normal. They had not required subjects more stimulating than those ordinary problems or appearances of life and nature which are always present. Their technical acquirements were as adequate as ever and they took up the task of expression where it had been interrupted.

There are many mansions in the house of poetry; the art is most varied and adaptable; we must acknowledge its adequacy for all forms and purposes of expression,—from the lampoon, through the satire, through mere description and narrative, through the epic, to the higher forms of the lyric and the drama. Rhythm, being the very breath and blood of all art, here lends itself dispassionately and without revolt to the lowest drudgery as well as the highest inspiration. But when so often calling on the name of poetry, I am thinking of that element in the art which is essential, in which the power of growth resides, which is the winged and restless spirit keeping pace with knowledge and often beating into the void in advance of speculation: the spirit which Shakespeare called "the prophetic soul of the wide world dreaming on things to come". This spirit endeavours to interpret the world in new terms of beauty, to find unique symbols, images and analogies for the varied forms of life. It absorbs science and philosophy, and anticipates social progress in terms of ideality. It is rare, but it is ever present, for what is it but the flickering and pulsation of the force that created the world.

I remarked a moment ago upon the remoteness of that mood of Matthew Arnold in which he expresses soul weariness and the need of self-dependence. Arnold advises the soul to learn this self-poise from nature pursuing her tasks, to live as the sea and the mountains live. But our modern mood does not seek self-dependence, having no knowledge of that lack, nor does it refer to the unconscious for comfort or example. It asks for deeper experience, for more intense feeling and for expression through action. Science has taught the modern that nature lives and breathes, and in looking at the mountains and the sea, he is moved to feelings based on growing knowledge, unutterable as yet in thought. The modern feels no sickness of soul which requires a panacea of quiescence; he is aware of imperfections and of vast physical and social problems, but life does not therefore interest him less but more. He has the will to live and persistence to grapple with the universal complexities. This becomes evident in the revolt against established forms and in the intellectual daring that forces received opinion before a new jurisdiction.

This is a critical age and has its peculiar tone of criticism. Compared with other times it more loudly and insistently questions and mocks at the past—the past exists merely "to be the snuff of younger spirits whose apprehensive senses all but new things disdain". Art that takes on new forms has more than ever a critical outlook, and the criticism seems to be based on irritation. The purpose of the effort is not so much, if at all, to create beauty, as to insult older ideas of beauty, to *épater le bourgeois*, to shock with unwholesome audacities, to insert a grain of sand into each individual oyster shell and set up an irritation, seemingly without any hope of ultimately producing pearls thereby, but with the mere malicious design of awakening protest, the more violent the better. I might continue my quotation of Shakespeare, and say of these ultra modern minds that their "Judgments are mere fathers of their garments, whose constancies expire before their fashions"; but no matter how long the present fashion lasts it, may be treated in retrospect as a moment of irony.

A virus has infected all the arts; the desire for rebellious, violent and discordant expression has invaded even the serene province of Music.

The extremists in this art invoke satire as their principal divinity. They set out to describe, for example, the feelings of the heir of a maiden aunt who has left him her pet dog instead of fifty thousand pounds. They write waltzes for the piano with the right-hand part in one key, and the left-hand part in another. Masses of orchestral sound move across each other careless of what happens in the passing.

Perhaps I might be pardoned a short digression here on the subject of Music,—its true progress in the path of perfection; for Music is the art of perfection, and, as Walter Pater declared, all other arts strive towards the condition of Music. The rise and development of modern Music is a matter of barely five hundred years and parallels the growth of modern Science. The developments of both in the future cannot be limited. They may progress side by side,—Science expanding and solving the problems of the universe, and Music fulfilling the definition that Wagner made for it as "the innermost dream-image of the essential nature of the world". Wagner's music was once satirically called the "Music of the Future". It is now firmly and gloriously fixed in the past. But Music is truly the art of the future. Men will come to it more and more as the art which can express the complex emotions of life in terms of purest beauty. It is the art most fitted to give comfort and release to the spirit and to resolve scepticism as it resolves discords. Side by side with a tone of supersensualism that runs through modern Music we have intellectual developments and also a straining towards spiritual thoughts which restore the balance. It is gratifying to note that Britain is taking the place she once occupied as a leader in musical creation. The obstacle to the understanding of Music has not been the absence of natural correspondences in the mind, Music has universal appeal, but the fact that it must reach the understanding through the ear. It must be twice created, and the written stuff is dumb until awakened into vibrating life. The invention of mechanical means for the reproduction of Music and their gradual improvement has made Music as accessible as the reproductions of fine paintings. The widespread use of these music machines proves the desire of the people to hear and to understand, and the effect upon the public taste will be appreciable. The style of amateur performances will be improved, and it may not be too much to claim for this wide distribution of beautiful and deeply felt music an influence on the creative side and a stimulation to eager youthful spirits to translate their emotions into sound. Music is the great nourisher of the imagination, and the prevalence of great music means the production of great verse. Over and against the poets who have been deaf to the stimulation of Music we can quote some of the greatest who have been sensitive to it,—Shakespeare, Milton, Keats, and I may quote the remark of Coleridge, made in 1833: "I could write as good verses as ever I did if I were perfectly free from vexations and were in the *ad libitum* hearing of fine music, which has a sensible effect in harmonizing my thoughts, and in animating and, as it were, lubricating my inventive faculties".

The leaders of what is called the "New Movement in Poetry" have some ground for argument, but make unconvincing uses of it. The most voluble centres of the New Movement are in the United States, and the subject is pursued with all the energy and conviction that we have learned to expect from the adoption of any cause to the south of us. We must willingly confess that Americans are an art-loving people, and that now they are immensely interested in all the arts. From the first they were hospitable to foreign production and absorbed all that was best in the work of other nationalities, and lately they have grown confident of their native artists and reward them with patronage and praise.

The protagonists of the Modern Movement in Poetry are most hospitable to the old poets; they are orthodox in their inclusions and throw a net wide enough to catch all the masters of the art from the earliest to the latest times. They approve of poets of our own day who use the established verse-forms as well as the writers of vers-libre and the innovators. Their quarrel, therefore, must be with the poetasters, with the slavish imitators, with the purveyors of conventional ideas and the innumerable composers of dead sonnets. But these people have always been among us and have always been intolerable to the children of light. The weariness they occasion is no new experience. They at once fastened themselves on the New Movement and welcomed vers-libre as the medium which would prove them poets. In proclaiming freedom as the war cry of the New Movement, the leaders admitted all the rebels against forms which they had never succeeded in mastering, and while they poured into vers-libre a vast amount of loose thinking and loose chatter, as if freedom were to include license of all kinds, they were still unable to master the form or prevail in any way except to bring it into contempt. The avowed object of the Movement is "a heroic effort to get rid of obstacles that have hampered the poet and separated him from his audience", and "to make the modern manifestations of poetry less a matter of rules and formulae and more a thing of the spirit and of organic as against imposed rhythm". A praiseworthy ideal! But has the poet ever been separated from his audience? Can poetry be made more than it ever was, a thing of the spirit? Did Browning separate himself from his audience when he cast his poem "Home Thoughts from Abroad" into its irregular form? Can one create a poem of greater spirituality than Vaughan's "I Saw Eternity the Other Night"? To exorcise this senseless irritation against rhyme and form, those possessed should intone the phrases of that great iconoclast, Walt Whitman, written in the noble preface to the 1855 edition of "Leaves of Grass". "The profit of rhyme is that it drops seeds of a sweeter and more luxuriant rhyme, and of uniformity that it conveys itself into its own roots in the ground out of sight. The rhyme and uniformity of perfect poems show the free growth of metrical laws, and bud from them as unerringly and loosely as lilacs and roses on a bush, and take shapes as compact as the shapes of chestnuts and oranges, and melons and pears, and shed the perfume impalpable to form".

All that I intend to inveigh against in these sentences is the cult that seeks to establish itself upon a false freedom in the realm of art. Sincerity, or, if you will, freedom, is the touchstone of poetry—of any and all art work in fact. Originality is the proof of genius, but all geniuses have imitated. Poetry is an endless chain of imitation, but genius comes dropping in, adding its own peculiar flavour in degree. Sainte Beuve has written it down,—"The end and object of every original writer is to express what nobody has yet expressed, to render what nobody else is able to render. . . .". This may be accepted as axiomatic, it governs production here and elsewhere, present and future, and any literary movement is doomed to failure if it attempts to pre-empt the conception that poetry should be original, should be freshened constantly by the inventions of new and audacious spirits.

The desire of creative minds everywhere is to express the age in terms of the age, and by intuition to flash light into the future. Revolt is essential to progress, not necessarily the revolt of violence, but always the revolt that questions the established past and puts it to the proof, that finds the old forms outworn and invents new forms for new matters.

It is the mission of new theories in the arts, and particularly of new theories that come to us illustrated by practice, to force us to re-examine the grounds of our perferences, and to retest our accepted dogmas. Sometimes the preferences are found to be prejudices and the dogmas hollow formulae. There is even a negative use in ugliness that throws into relief upon a dark and inchoate background the shining lines and melting curves of true beauty. The latest mission of revolt has been performed inadequately, but it has served to show us that our poetic utterance was becoming formalized. We require more rage of our poets. We should like them to put to the proof that saying of William Blake: "The tigers of wrath are wiser than the horses of instruction".

I may possibly have taken up too much time in referring to modern tendencies in poetry, which are only ephemeral, and in combating the claim, put forward with all gravity, to distinction that flows from a new discovery. Already many of these fads have faded or disappeared. The constancies of these bright spirits have expired before their fashions. They are already absorbed with a new fad. But let it pass,—modernity is not a fad, it is the feeling for actuality.

If I am ever to make good the title imposed on this address, I must soon do so, and trace a connection between Poetry and Progress, if there be any. Maybe we shall find that there is no connection, and that they are independent, perhaps hostile. It is certain that Poetry has no connection with material progress and with those advances which we think of as specialties of modern life—the utilization of electricity for example. Euripides living in his cave by the seashore, nourished and clothed in the frugalist and simplest fashion, has told us things about the human spirit and about our relation to the gods which are still piercingly true. Dante's imagination was brooding and intense within the mediaeval walls of Tuscany. Shakespeare, when he lodged in Silver Street with the Mountjoy's, was discomfortably treated, judged by our standards, and yet he lives forever in the minds of men. It is useless to elaborate this trite assertion; if material progress, convenience, comfort, had any connection with poetry, with expression, our poets would be as much superior to the old poets as a nitrogen electric bulb is to a rush light. Poetry has commerce with feeling and emotion, and the delight of Nausicaa as she drove the mules in the high wain heaped with linen to the river shore, was not less than the joy which the modern girl feels in rushing her motor car along a stretch of tar-macadam. Nausicaa also was free of her family for a while and felt akin to the gull that turned on silver wing over the bay; felt the joy of control over the headstrong mules, and the clean limbed maidens who tossed the ball by the wine-dark sea.

The feeling of delight is the thing, not its cause, and if there be any progress in the art of poetry, it must be proved in the keenness with which we feel the expression of the emotion. But the emotion gives rise to correspondences. What were the trains of thought set up in the Greek hearers who listened to the recital of that little journey of Nausicaa to the swift running river with the family washing? We can imagine they were simple enough, and we can compare them with the collateral ideas set up by the description of a journey in a high-power car set forth in that profane poem on Heaven by one of the moderns. The power of poetry has here expanded to include a world unknown to Greek expression. Here is progress of a sort. The poetry of the aeroplane has yet to be written, but, when it comes, it will pass beyond the expressions of bird-flight in the older poets and will awaken images foreign to their states of feeling. Shakespeare wrote of the flower that comes before the swallow dares and takes the world with beauty. The aeroplane has a beauty and daring all its own, and the future poet may associate that daring with some transcendent flower to heighten its world-taking beauty. Here may be found a claim for progress in poetry, that it has proved adequate to its eternal task and gathers up the analogies and implications, the movement and colour of modern life—not as yet in any supreme way, but in a groping fashion. It is far-fetched to compare the work of Homer to that of a lively modern—an immortal to one of those who perish—but how many poets perished in the broad flood of Homer? Immortal! The idea becomes vague and relative when we think of the vestiges of great peoples, confused with the innumerable blown sand of deserts, or dissolved in the brine of oblivious oceans, lost and irretrievable. Art is immortal, not the work of its votaries, and the poets pass from hand to hand the torch of the spirit, now a mere sparkling of light, now flaming gloriously, ever deathless.

If this be one contact between Poetry and Progress there may be another in the spread of idealism, in the increase in the poetic outlook on life, which is, I think, apparent. The appeal of poetry has increased and the number of those seeking self-expression has increased. The technique of the art is understood by many and widely practised with varying success, but with an astonishing control of form. This may be regretted in some quarters. One of our distinguished poets was saying the other day that there are too many of us,—too many verse writers crowding one another to death. My own complaint, if I have any, is not that we are too many, but that we do not know enough. Our knowledge of ourselves and the world about us and of the spirit of the age, the true spring of all deep and noble and beautiful work, is inadequate.

There is evidence of Progress in the growing freedom in the commerce and exchange of ideas the world over. Poetic minds take fire from one another, and there never was a time when international influences were so strong in poetry as they are to-day. France and Italy have, from the time of Chaucer, exerted an influence on the literature of England. The influence is still evident, and to it is added that of the Norse countries, of Russia and of Central Europe. Oriental thought has touched English minds, and in one instance gave to an English poet the groundwork for an expression in terms of final beauty of the fatalistic view of life. Of late, mainly through the work of French savants, the innumerable treasures of Chinese and Japanese poetry have been disclosed and have led poets writing in English to envy them the delicate touch, light as "airy air", and to try to distill into our smaller verse forms that fugitive and breath-like beauty. English poetry has due influence on the Continent, and there is the constant inter-play of the truest internationalism, the internationalism of ideals and of the ever-changing, ever-advancing laws of the republic of beauty. National relations will be duly influenced by this free interchange of poetic ideals, and the ready accessibility of new and stimulating thought must eventually prevail in mutual understanding. We can resolutely claim for Poetry a vital connection with this Progress.

In these relationships between Poetry and Progress, Poetry is working in its natural medium as the servant of the imagination, not as the servant of Progress. The imagination has always been concerned with endeavours to harmonize life and to set up nobler conditions of living; to picture perfect social states and to commend them to the reason. The poet is the voice of the imagination, and the art in which he works, apart from the conveyed message, is an aid to the cause, for it is ever striving for perfection, so that the most fragile lyric is a factor in human progress as well as the most profound drama. The poets have felt their obligation to aid in this progress and many of them have expressed it. The "miseries of the world are misery and will not let them rest", and while it is only given to the few in every age to crystalize the immortal truths, all poets are engaged with the expression of truth. Working without conscious plan and merely repeating to themselves, as it were, what they have learnt of life from experience, or conveying the hints that intuition has whispered to them, they awaken in countless souls sympathetic vibrations of beauty and ideality: the hearer is charmed out of himself, his personality dissolves in the ocean of feeling, his spirit is consoled for sorrows which he cannot understand and fortified for trials which he cannot foretell. This influence is the reward of the poet and his beneficiaries have ever been generous in acknowledging their debt. The voices are legion, but let me choose from the multitude as a witness one who was not a dreamer, one who was a child of his age and that not a poetical age, one who loved the excitement of an aristocratic society, insolent with the feeling of class, dissolute and irresponsible, one whose genius exerted itself in a political life, soiled with corruption and intrigue but dealing with events of incomparable gravity. Charles James Fox said of poetry: "It is the great refreshment of the human mind" . . . "The greatest thing after all". To quote the words of his biographer, the Poets "consoled him for having missed everything upon which his heart was set; for the loss of power and fortune; for his all but permanent exclusion from the privilege of serving his country and the opportunity of benefiting his friends".

I should like to close this address upon that tone, upon the idea of the supremacy of poetry in life—not a supremacy of detachment, but a supremacy of animating influence—the very inner spirit of life. Fox felt it in his day, when the conditions in the world during and after the French Revolution were not very different from the confused and terrifying conditions we find around us now. He took refreshment in that stream of poetry, lingering by ancient sources of the stream, the crystal pools of Greece and Rome. The poetry of his day did not interest him as greatly as classical poetry, but it did interest him. The poetry of the 18th century was a poetry with the ideals of prose: compared with the Classics and the Elizabethans, it lacked poetic substance. The poetry of our day may not satisfy us, but we have, as Fox had, possession of the Classics and the Elizabethans, and we have, moreover, the poetry of a later day than his that is filled with some of the qualities that he cherished.

If the poetry of our generation is wayward and discomforting, full of experiment that seems to lead nowhither, bitter with the turbulence of an uncertain and ominous time, we may turn from it for refreshment to those earlier days when society appears to us to have been simpler, when there were seers who made clear the paths of life and adorned them with beauty.

APPENDIX B

THE METEOROLOGICAL SERVICE OF CANADA

BY

SIR FREDERIC STUPART, Kt. F.R.S.C.
Director, Dominion Meteorological Service.

METEOROLOGICAL SERVICE OF CANADA

As time goes on it becomes more and more obvious that climatic records are essential to the development of the country. Agriculture and Power developments are industries particularly dependent on temperature and rainfall and the Meteorological Service is being continually pressed to increase the number of observing stations. At the present time there are 646 observing stations, an increase of 12 from last year. At 293 of these stations the observer is paid a salary for the duties performed, but it is only at Toronto, Victoria, Edmonton, Moose Jaw, Winnipeg, Quebec and St. John, that the observers are paid for whole time work. In the majority of instances the stipend is very small. At 353 stations the observing is performed voluntarily by men who take an interest in Meteorological records.

For purposes of administration the work of the Central Office is divided into divisions as follow:

Forecasts.—Synoptical charts of the North American Continent, Western Europe, and the North Atlantic Ocean, have been compiled twice daily from reports received by telegraph, cable and wireless, and from study of the atmospheric movements shown by these charts, forecasts of the probable weather for the next 36 hours in Canada and Newfoundland and adjacent waters have been issued, and when deemed necessary storm warnings have been issued to ports on the Great Lakes, and Gulf of St. Lawrence, and on the Atlantic and Pacific coasts.

Climatology.—This Division prepares monthly and annual bulletins and detailed reports with maps, diagrams, etc., on current weather in all parts of Canada, Newfoundland and Bermuda, supplies weather data to railways and litigants to decide disputes and claims founded on damage through effects of weather. Upon request it furnishes special studies of extremes and averages of temperature, precipitation, wind movement, etc., in specified districts to water-power and construction engineers, settlers, physicians and others.

It prepares and issues comprehensive reports and atlases on the climate of the various provinces embodying results of weather observations during the period since Confederation, and also prepares shorter articles on related subjects for inclusion in bulletins of other governmental departments and of provincial governments, boards of trade, etc.

The study of Canadian crops in relation to weather changes has also been continued. A method of studying graphically the yields of wheat in the Canadian West in relation to the seasonal changes in the prevailing winds of the North Temperate Zone was devised during the year and explained before the Toronto meeting of the American Meteorological Association. The maps made in this connection showed the futility of attempts at artificial rain-making and also showed that for the southwestern districts of the wheat region frequently recurring dry years are normal and that, therefore, irrigation canals should always be kept in good repair from season to season, even in years of ample rainfall.

Having regard to the growing interest in Canada with respect to problems of reforestation this Division has instituted a study of variations in the growth of pine and spruce in order to trace the effect of the weather changes and of local climates. At the present time sections of aged felled trees, or even of stumps, are easily obtained and the date of the last annual ring identified with certainty. A collection of such sections from different parts of Canada is being made and correlations of annual ring-growth with weather computed. It is proposed to increase the collection by having paper-impressions made wherever possible by Meteorological inspectors in future when on annual inspections of out-lying stations.

Magnetics.—Photographic records of the variations taking place in the Magnetic elements during the fiscal year 1921-22 were obtained at Agincourt with only very slight loss. Pronounced disturbances were of very infrequent occurrence as was expected in a year of minimum sunspots.

On the 12th of May, however, a very remarkable series of disturbances began which lasted until the 21st, and were repeated at each rotation of the sun for several months, although with much diminished energy. During the May disturbance the limits of our recording instruments were exceeded and for several hours the record was lost. In Declination the range was greater than 4° and in Horizontal Force nearly 1200γ, which is almost 8% of the normal value.

Absolute observations for D, H and I were made each week and base values for the differential instruments determined from them.

Tables showing the Magnetic character of each day of the year were prepared and copies forwarded to the International Commission on Terrestrial Magnetism. The "Selected days" of the commission are used in the analysis of the Magnetic data for our Annual Magnetic Report.

At the request of the Surveyor General, index corrections for compasses attached to Surveyors' theodolites to the number of sixty were determined and the results forwarded to him. Assistance was also given to members of his staff in determining the constants of their Total Force Instruments both before and after their field work.

Members of the staff of the Dominion Observatory were also assisted in standardizing their magnetometers and Dip Circles.

Many special reports were made for enquirers and surveyors who required data for specified places and times.

A Report was also made of the work of the Canadian Magnetic Observatories and of the Intercomparison of Magnetic instruments in Canada for presentation at the Rome Meeting of the International Geodetic and Geophysical Union.

The Observatory at Meanook was continued in operation as before. During the very cold weather some loss of record occurred owing to stopping of the driving clock.

Weekly observations were made of absolute Declination and Inclination and twice a month observations of Horizontal Force.

The Declination photographic traces for both Agincourt and Meanook were loaned to the Surveyor General and the Agincourt Declination traces to the Dominion Observatory for use in the reduction of their field work.

The accompanying tables give a summary of the results obtained at Agincourt and Meanook during the fiscal year 1921-22.

Summary of Results of Magnetic Observations Made at Agincourt During the Fiscal Year 1921-22

Month	Mean Monthly Values			
	D West	H	Z	I
1921	° ′	γ	γ	° ′
April	6 49.4	15851	58087	74 44.2
May	50.2	31	83	45.2
June	49.7	46	73	44.2
July	50.1	43	64	44.3
August	51.0	37	47	44.4
September	51.8	26	46	45.0
October	52.5	22	31	44.9
November	53.2	25	22	44.7
December	53.6	25	20	44.6
1922				
January	53.8	21	17	44.8
February	54.6	17	00	44.8
March	55.2	10	00	45.1

Agincourt Daily and Monthly Ranges

Month	D			H			Z		
	Mean Daily Range		Absolute Monthly Range	Mean D. Range		Absolute Monthly Range	Mean D. Range		Absolute Monthly Range
	From Hourly Readings	From Max. & Min.		From Hourly Read'gs	From Max. & Min.		From Hourly Readings	From Max. & Min.	
1921	′	′	° ′	γ	γ	γ	γ	γ	γ
April	10.4	21.6	1 04.9	36	82	476	17	36	268
May	12.6	48.2	4 20.0	103	213	1166	57	168	1148
June	12.3	18.6	0 57.4	33	64	171	10	25	123
July	15.0	21.2	0 44.9	39	67	137	12	29	109
Aug.	14.6	20.1	0 38.1	44	72	171	14	33	149
Sept.	12.4	21.6	1 48.5	41	78	557	12	41	438
Oct.	9.5	20.1	1 55.0	34	74	506	24	48	706
Nov.	7.5	15.4	1 24.0	22	53	190	13	27	150
Dec.	6.3	18.3	0 59.4	20	58	172	8	23	112
1922									
Jan.	5.5	17.3	0 51.5	27	54	150	8	27	185
Feb.	6.6	19.0	0 57.2	16	62	261	11	29	159
March	9.3	21.2	0 51.3	31	93	469	24	51	272

Summary of Results of Magnetic Observations Made at Meanook During the Fiscal Year 1921-22

Month	Mean Monthly Values			
	D East	H	Z	I
1921	° ′	γ	γ	° ′
April	27 34.9	12901	60169	77 53.9
May	33.5	896	172	54.2
June	33.5	908	202	53.9
July	31.9	910	186	53.6
August	31.6	902	123	53.3
September	31.3	903	213	54.3
October	30.7	896	189	54.4
November	31.4	910	245	54.3
December	30.8	908	142	53.2
1922				
January	31.8	908	176	53.6
February	32.4	920	189	53.1
March	30.1	890	115	53.7

Meanook Daily and Monthly Ranges of D

Month	From hourly readings	From Max. and Min.	Absolute Monthly range
1921	′	′	° ′
April	13.7	48.3	3 56.9
May	17.7	73.6	6 16.2
June	16.2	26.4	1 07.1
July	15.0	28.6	1 31.3
August	14.9	33.5	2 57.0
September	13.0	39.0	3 43.0
October	9.4	39.2	3 57.2
November	7.5	27.9	2 12.9
December	5.9	31.7	2 12.0
1922			
January	5.3	31.1	2 26.6
February	7.1	49.8	4 21.3
March	11.8	50.5	3 59.1

Atmospheric Physics.—Pilot Balloon work was carried on at Toronto and Camp Borden, Ont., throughout the year and at Ottawa, Ont., Roberval, P.Q., and High River, Alta., during the flying season. New stations were opened at Halifax, N.S., and Victoria Beach, Man., at the Aerodromes of the Air Board, and at Victoria, B.C., in connection with the Meteorological Service. A book of tables for readily obtaining the horizontal distance of the balloon from the station at any minute was prepared and published. This book, in conjunction with the special plotting board, enables the observer to very quickly obtain the direction and velocity of the wind at various heights. Balloons have been despatched regularly from these stations whenever the weather permitted. The highest flight obtained at Toronto was on the 13th July, 1921, when the balloon was followed for 99 minutes and reached a height of 52,000 ft. The highest flight obtained in Canada up to the present occurred on the 26th January, 1922, at Camp Borden, when the balloon was followed for 106 minutes and reached a height of nearly 56,000 ft.

Balloons carrying instruments were sent up from Woodstock, Ont., on the international days and the recoveries were very good until January, 1922, when six balloons were sent up and only two found. To obtain upper air data in the West, arrangements were made in October for sending up balloons with instruments from Calgary, Alta., and of those sent up about half have been found. The international committee has altered the procedure in sending up the balloons. Hitherto there were six consecutive flights in one month of the year, three consecutive flights in three months and one flight in each of the remaining months. According to the new procedure there are to be but three definite periods of six flights each in the year, and for one of the periods the ascents are to take place every twelve hours.

The Meteorological Service had undertaken, as their part of the international programme in connection with Amunsden's Expedition, to send an observer to Fort Good Hope, Mackenzie River district, to take pilot balloon, meteorological and magnetic observations during the year July, 1921-July, 1922. Although Capt. Amunsden has had to postpone his part of the programme the Meteorological Service carried out its part and sent Mr. Harold Bibby to Fort Good Hope. He reached his destination on the 11th July and will return in July of this year. The reports received by the winter mail indicate that the instruments were all working satisfactorily.

Two types of thermometers for use on board ship to take the temperature of ocean water in the Pacific were tried out during the year. One was a thermograph of the Bristol type. It consisted of a steel bulb filled with mercury inserted in the intake pipe to the condenser and connected by fine steel capillary tubing to the registering part. The other was a resistance thermometer inserted in the intake and connected to a Wheatstone Bridge which was adjusted by a special rheostat so that the temperature read directly on a scale to a fifth of a degree. Readings were taken every four hours. While the tubes exposed to the action of the sea water were made of steel or iron, and were practically the same as the pipes in which they were inserted, yet the corrosion was so great that it very soon destroyed the thermometers. This defect is now being remedied, as well as some other minor defects that developed in the resistance thermometer.

Earth temperature thermometers were almost ready for installation last Fall but the freezing of the ground prevented them from being put in. It is proposed to put in a set of thermometers at depths of 4″, 10″, 20″ and 40″ to be recorded for a period of eight minutes once in every sixty-four and a surface thermometer to be recorded three times in this interval. Thermometers at the depths 5 ft., 6 ft., 9 ft. and 15 ft., to be read once daily, will also be installed.

Through the courtesy and assistance of Mr. Parkins, of the University of Toronto, extensive observations were made in the Wind Tunnel of the University on the anemometer and much valuable information on the action of the wind on the anemometer has been obtained. The Meteorological Service desires to take this opportunity of expressing to Mr. Parkins and his assistants its grateful appreciation of the services they rendered and of making it possible to carry out the investigation.

Seismology.—The Milne Seismographs at Toronto and Victoria have been kept in operation throughout the year with little loss of record. No alterations were made in their adjustments, the booms being steady at a period of 18 seconds.

Toronto recorded 93 disturbances, 45 less than last year, and 37 less than the average number for the past seven years.

The month of May with 13, and August and December with 3, show the greatest and the least number recorded in any month of the year.

Phenological Observations, 1921

The following report on the phenological observations of 1921 is presented by Mr. F. F. Payne of the Central Office of the Meteorological Service.

The number of phenological reports received from observers other than those from Nova Scotia was 34, and although attempts were made to enlist the services of others the increase over those of 1920 was only two. The work being purely voluntary and requiring much attention only those deeply interested are inclined to take it up.

The general summary for Nova Scotia kindly supplied by Dr. A. H. MacKay, Superintendent of Education, Halifax, and prepared by ten regional assistants is a model of the work which might be undertaken by educational departments in other provinces and which would be valuable for both educational and climatological purposes. Credit is also due to Mr. W. H. Magee, Inspector of Schools, North Battleford, for valuable assistance in procuring observers in Saskatchewan.

In British Columbia vegetation during the Spring was somewhat backward but it improved late in May. In Alberta and Manitoba early flowering plants were in bloom on dates in advance of the normal but later growth was somewhat retarded. In Saskatchewan vegetation generally made rapid progress in the Spring and the dates of flowering were unusually early. In Ontario, Quebec and the Maritime Provinces the dates were considerably in advance of the normal.

The Province of Nova Scotia is divided into its main climatic slopes or regions which are not, in some cases, co-terminous with the boundaries of the counties. Slopes, especially those to the coast, are subdivided into (*a*) coast belts, (*b*) inland belts, and (*c*) high inland belts. Where these letters appear in the tables they refer to these slopes or regions. Dates for slopes IX and X were combined in computing the average for the province. The following regions are marked out, proceeding from south to north and from east to west as orderly as it is possible.

Region of Slopes	Belts
I. Yarmouth and Digby Counties......	(*a*) Coast, (*b*) Low inlands, (*c*) High inlands.
II. Shelburne, Queens and Lunen'g Co's..	" "

III.	Annapolis and Kings Counties.......(*a*)	South Mts.,(*b*) Annapolis Valley, (*c*) Cornwallis Valley, (*d*) North Mts.
IV.	Hants and South of Cobequid Bay...(*a*)	Coast, (*b*) Low inlands, (*c*) High inlands.
V.	Halifax and Guysboro Counties......	" "
VI.	(a) Cobequid Slope to S (b) Chignecto Slope to N.W...................(*a*)	Coast, (*b*) Inlands.
VII.	North'rland Sts. Slopes (to the north).(*a*)	Coast, (*b*) Low inlands, (*c*) High inlands.
VIII.	Richmond & Cape Breton Co.'s......	" "
IX.	Bras d'Or Slope (to the southeast)...	" "
X.	Inverness Slope (to Gulf, northwest).	" "

Owing to the great number of observers and others taking part in the production of the tables for Nova Scotia, their names are omitted from the following list.

List of Stations and Observers

W. S. Moore, Agassiz, B.C.
Stanley Bayne, Alberni, B.C.
A. B. Taylor, Atlin, B.C.
A. C. Murray, Fort St. James, B.C.
Mrs. Hugh Hunter, Princeton, B.C.
John Strand, Quesnel, B.C.
Geo. W. Johnson, Summerland, B.C.
A. S. Barton, Victoria, B.C.
W. Wallace, F.R.S.E., Camsie, Alta.
Mrs. W. L. Fulton, Halkirk, Alta.
Thos. B. Waite, Ranfurly, Alta.
N. C. Qua, Vermilion, Alta.
R. L. Clarke, Arcola, Sask.
Pupils of Eight Mile Lake, South Battleford, Sask.
William Brown, Dundurn, Sask.
H. W. McCrae, Expanse, Sask.
R. H. Carter, Senior and Junior, Fort Qu'Appelle, Sask.
Geo. Lang, Indian Head, Sask.
Pupils Ellastone School, Lilac, Sask.
H. E. Grose, Mortlach, Sask.

M. D. Barker, Saltcoats, Sask.
M. Milliken, Scott, Sask.
C. W. Bryden, Shellbrook, Sask.
Allan Campbell, Brandon, Man.
H. S. W. Clarke, Forrest, Man.
Manitoba Sanatorium, Ninette, Man.
A. Goodridge, Oakbank, Man.
E. Willett, Treherne, Man.
Miss M. Moffitt and Pupils, Cape Croker, Ont.
Miss H. M. Meighen, Perth, Ont.
Mrs. W. T. Gale, Rutherglan, Ont.
F. F. Payne, Toronto, Ont.
David McKenzie, Abitibi, Que.
T. F. Ritchie, Lennoxville, Que.
Wm. H. Moore, Scotch Lake, N.B.

PHENOLOGICAL OBSERVATIONS
CANADA
1921

PHENOLOGICAL OBSERVATIONS, CANADA, 1921

YEAR 1921

Day of year corresponding to last day of each month

Month	Day	Month	Day
January	31	July	212
February	59	August	243
March	90	September	273
April	120	October	304
May	151	November	334
June	181	December	365

When first seen

Observation	Agassiz, B.C.	Alberni, B.C.	Atlin, B.C.	Fort St. James, B.C.	Princeton, B.C.	Quesnel, B.C.	Summerland, B.C.	Victoria, B.C.	Camsie, Alta.	Halkirk, Alta.	Ranfurly, Alta.	Vermilion, Alta.
1. Alder (Anus incana) ... Shedding pollen		93	122		72							
2. Canada Thistle (Cirsium arvense) ... Flowering	182	188			182	209	168	193				
3. Trailing Arbutus (Epigaea repens) ... "												
4. Dandelion (Taraxacum officinale) ... "	85	96	150		110	122	105	74		135	119	
5. Violet, Blue (Viola palmata cucullata) ... "	103	108	154		111	115		60	110	142	120	
6. Violet, White (Viola blanda) ... "					121	119		62			128	
7. Columbine (Aquilegia) ... "	131	150	163		149	154	124	121			175	
8. Trees appear green ...	94	110	144		130	89	115	89		137	132	
9. Red Clover (Trifolium pratense) ... Flowering	121	150			163	133		146				
10. White Clover (Trifolium repens) ... "		148			150	137	137	142			145	
11. Wild Raspberry (Rubus strigosus) ... "		151	191		159	184					154	
12. Cultivated Currant (Ribes rubrum) ... "	101	109			130			90		144	142	
13. Wild Rose (Rosa) ... "	136	149	167		148	148	148	138		167	164	
14. Trillium (Trillium) ... "	83	97						87				
15. Anemone (Anemone) ... "	115		114		148					121	115	
16. Maple (Acer) ... "	105	118						94			129	
17. Strawberry Wild (Fragaria Virginiana) ...	124	106	161	143	118	124		85		121	139	
18. Strawberry Wild (Fragaria Virginiana) ... Fruit ripe	145	152		181	159	158		156			161	
19. Crocus, Cultivated (Crocus) ... Flowering	57	70					81	35			132	107
20. Lilac (Syringa vulgaris) ... "	126	133			144	139	136	125		160	161	
21. Apple (Pyrus malus) ... "	116	132			138		128	118		155	140	
22. Plum, Cultivated (Prunus domestica) ... "	83	128						93			138	
23. Cherry, Wild (Prunus) ... "	99	125						106			137	
24. Cherry, Cultivated (Prunus cerasus) ... "	99	115					111	95			142	

When becoming common

Observation	Agassiz, B.C.	Alberni, B.C.	Atlin, B.C.	Fort St. James, B.C.	Princeton, B.C.	Quesnel, B.C.	Summerland, B.C.	Victoria, B.C.	Camsie, Alta.	Halkirk, Alta.	Ranfurly, Alta.	Vermilion, Alta.
1. Alder (Anus incana) ... Shedding pollen					74							
2. Canada Thistle (Cirsium arvense) ... Flowering	201	227			188			204				
3. Trailing Arbutus (Epigaea repens) ... "												
4. Dandelion (Taraxacum officinale) ... "	97				117	130		96		141	125	
5. Violet, Blue (Viola palmata cucullata) ... "	113	131			117	126		69			127	
6. Violet, White (Viola blanda) ... "					128	130		71				
7. Columbine (Aquilegia) ... "	141				151	161					179	
8. Trees appear green ...	106							100			140	
9. Red Clover (Trifolium pratense) ... Flowering	130	180			168			155				
10. White Clover (Trifolium repens) ... "					158	144					150	
11. Wild Raspberry (Rubus strigosus) ... "		157									161	
12. Cultivated Currant (Ribes rubrum) ... "	105	130						98		145	146	
13. Wild Rose (Rosa) ... "	143	177		158	156	155		145		172	171	
14. Trillium (Trillium) ... "	88	128						116				
15. Anemone (Anemone) ... "	124				152					121	117	
16. Maple (Acer) ... "	114	126						102			132	
17. Strawberry Wild (Fragaria Virginiana) ...	133	111			127			105		145	145	
18. Strawberry Wild (Fragaria Virginiana) ... Fruit ripe	150	157		185	161						166	
19. Crocus, Cultivated (Crocus) ... Flowering	69							60			138	
20. Lilac (Syringa vulgaris) ... "	132	150			147			132			165	
21. Apple (Pyrus malus) ... "	131	146			141			130		155	147	
22. Plum, Cultivated (Prunus domestica) ... "	99	135						107			144	
23. Cherry, Wild (Prunus) ... "	103	136						110			140	
24. Cherry, Cultivated (Prunus cerasus) ... "	105	136				104		104			148	

136	115			63	94	70	52			154		25. Buttercup (Ranunculus acris) .... "	142	151			74			89			159
144												26. Yellow Pond Lilly (Nuphar advena) .... "	151										
137	150						54			140		27. Blue-eyed Grass (Sisyrinchium) .... "	142							69			142
	128	175	142	132	201	107	112			138		28. Saskatoon (Amalanchier Canadensis) .... "		136			135			120			140
208	178			183	196				200	183		29. Golden Rod (Solidago) .... "	218				194						188
	112	117	91	321	107		116	108	103	79		30. Wild Geese		118		114				121		204	87
		94	91	75	104			94	104	105	100	31. Wild Ducks				114	113	60				104	110
23	45	114	98	67	34	57		103	108	105	107	32. Robins (Turdus Migratorius)	56				79					104	110
23	148			62		57			90	103	109	33. Meadow Larks (Sturnella)	59				84	117				121	110
91	84	100	97	64	91	65	110	98				34. Blue Birds (Sialia sialis)	97				80					104	
				91	96					112		35. Flickers or Golden Woodpeckers (Colaptes auratus)					95						118
			103	108		94				57		36. Song Sparrows (Melospiza fasciata)					121						162
93	144	133	125	131	148	93	87	108		118		37. Swallows (Clivicola riparia)	141			120	137			100			121
			91					103		97	104	38. Juncoes (Junco hyemalis)				152							104
	187								152			39. Orioles (Icterus galbula)											
	43					146				129		40. King Birds (Tyrannus tyrannus)											134
112	99		147	133	194	121	100					41. Humming Birds (Trochilus colubris)	139				137			118			
41	56	123	121	107		111	42	102	106	107		42. Frogs Piping	79				108			84		110	
46				80		75				112		43. Earth Worm Casts (frost out of ground)	60										
		151	129							110		44. Lakes Open											120
			112	63								45. Rivers Open											
74	53		124	80	95	77	71		105	110		46. Ploughing	95	100			82			91			113
104	96			82	100	90	77		104	125	117	47. Sowing	123	105			94			100		117	132
150	181			171	192	155	157		201	201		48. Hay Cutting	187	206			173			183		206	209
211	228		206	238	227	192	210		221	216		49. Grain Cutting	221	231			244			228		227	222
82	130	138		120	134	130	60		138	140		50. Potato Planting	138	150			130			97		144	142

PHENOLOGICAL OBSERVATIONS, CANADA, 1921

YEAR 1921

Day of year corresponding to last day of each month

January	31	July	212
February	59	August	243
March	90	September	273
April	120	October	304
May	151	November	334
June	181	December	365

When first seen

Year 1921	Arcola, Sask.	Battleford, Sask.	Dundurn, Sask.	Expanse, Sask.	Indian Head, Sask.	Lilac, Sask.	Mortlach, Sask.	Saltcoats, Sask.	Scott, Sask.	Shellbrook, Sask.	Brandon, Man.	Forrest, Man.
1. Alder (Alnus incana)....Shedding pollen												131
2. Canada Thistle (Cirsium arvense)....Flowering	186		191	191	176		191	193				
3. Trailing Arbutus (Epigaea repens).... "												
4. Dandelion (Taraxacum officinale).... "	135		128	150	138	157	145	129	141	138	130	137
5. Violet, Blue (Viola palmata cuculata).... "	131		130	128	139	140	140	123	135	131		136
6. Violet, White (Viola blanda).... "	131		142		145		152		144		127	
7. Columbine (Aquilegia)..... "									144			
8. Trees appear green....	135	137	126		138	136	128	128	138	138	128	132
9. Red Clover (Trifolium pratense)....Flowering			176		171			171				
10. White Clover (Trifolium repens).... "			162		161		159	166				
11. Wild Raspberry (Rubus strigosus).... "			137		147		182	163	166			
12. Cultivated Currant (Ribes rubrum).... "	135		136		140		179	166	175			
13. Wild Rose (Rosa).... "		163	162	162	158	164	159	159	167	165		161
14. Trillium (Trillium).... "												
15. Anemone (Anemone).... "	97	92	91	105		116	105	110	114	117	105	109
16. Maple (Acer).... "					134		129	135	164		130	
17. Strawberry Wild (Fragaria Virginiana)....		133	142		147	143	157	159	151	129		
18. Strawberry Wild (Fragaria Virginiana)....Fruit ripe		172	180		143	171	181	177	171			
19. Crocus, Cultivated (Crocus)....Flowering					137							
20. Lilac (Syringa vulgaris).... "					150	154	156	151	157			
21. Apple (Pyrus malus).... "					142		159	156	153			
22. Plum, Cultivated (Prunus domestica).... "			148		141		159		145			
23. Cherry, Wild (Prunus).... "		144	148		143	152	159	153	176	142		166
24. Cherry, Cultivated (Prunus cerasus).... "												

When becoming common

Year 1921	Arcola, Sask.	Battleford, Sask.	Dundurn, Sask.	Expanse, Sask.	Indian Head, Sask.	Lilac, Sask.	Mortlach, Sask.	Saltcoats, Sask.	Scott, Sask.	Shellbrook, Sask.	Brandon, Man.	Forrest, Man.
1. Alder (Alnus incana)....Shedding pollen												
2. Canada Thistle (Cirsium arvense)....Flowering	191			196	185		196					
3. Trailing Arbutus (Epigaea repens).... "												
4. Dandelion (Taraxacum officinale).... "	152				143		153		145	144		140
5. Violet, Blue (Viola palmata cuculata).... "	138			133	148	156	150		143	138		141
6. Violet, White (Viola blanda).... "	138				161		154					
7. Columbine (Aquilegia)..... "									166			
8. Trees appear green....					145		132		146	144		
9. Red Clover (Trifolium pratense)....Flowering					176							
10. White Clover (Trifolium repens).... "					166							
11. Wild Raspberry (Rubus strigosus).... "					152		184		171			
12. Cultivated Currant (Ribes rubrum).... "					146				181			
13. Wild Rose (Rosa).... "				169	163		161		174			163
14. Trillium (Trillium).... "												
15. Anemone (Anemone).... "	107	120		107	106	121	115		121	124	107	114
16. Maple (Acer).... "					138				174			
17. Strawberry Wild (Fragaria Virginiana)....		144			152		161		157			
18. Strawberry Wild (Fragaria Virginiana)....Fruit ripe		171			152		156		176			171
19. Crocus, Cultivated (Crocus)....Flowering					142							
20. Lilac (Syringa vulgaris).... "					155		171		167			
21. Apple (Pyrus malus).... "					147				160			
22. Plum, Cultivated (Prunus domestica).... "					146				151			
23. Cherry, Wild (Prunus).... "					148		182		184	150		
24. Cherry, Cultivated (Prunus cerasus).... "												

		128	112	152		112	123	115	132	123		25. Buttercup (Ranunculus acris)	"				121	158		120		122	137		
				171								26. Yellow Pond Lily (Nuphar advena)	"					178							
		159		173	159	159		158				27. Blue-eyed Grass (Sisyrinchium)	"					181		161					
	144			142	143	159	153	144	144			28. Saskatoon (Amalanchier Canadensis)	"					146		166		149	150		
			206	196		186	196	186	195			29. Golden Rod (Solidago)	"				227	217		201		213			
74		85	64	59	109	92	81	105	93		104	30. Wild Geese		95			79	92		100		107			106
74	97	91	60	85	106	91	98	104	107		98	31. Wild Ducks		95			64	92		98		107			107
94	91	109	94	95	104	111	102	103	109	105	99	32. Robins (Turdus Migratorius)		110			104	101		118					106
84	91	87	91	90	100	93	124	103	103	88	97	33. Meadow Larks (Sturnela)		91			92	94		100					109
		106	85			90					99	34. Blue Birds (Sialia sialis)								100					105
100		108	105	105	135	109	121				101	35. Flickers or Golden Woodpeckers (Colaptes auratus)		110				112		115					103
106		62	105	102		113						36. Song Sparrows (Melospiza fasciata)		120			111	109		120					
123		148	150	145		129					133	37. Swallows (Clivicola riparia)					151	152		140					
93	81		93	90	110	101			104			38. Juncoes (Junco hyemalis)					94	94		105					
144			147	141		159						39. Orioles (Icterus galbula)		152				145		166					
143	107	135	141	147	155	130						40. King Birds (Tyrannus tyrannus)		152			153	152		150					
				147		210			179			41. Humming Birds (Trochius colubris)						152							
106	107	114	107	106	107	106	105	107	117	105	102	42. Frogs piping					112	110		114		115	124		107
		135		110		107		139			131	43. Earth Worm Casts (frost out of ground)						114							
	120	101	103	114	107	102	64					44. Lakes Open					120	114							
	110	107		100	107	108	105			102		45. Rivers Open						100							
100	117	108	106	108	118	106	108	117	122	108	104	46. Ploughing		106			109	115		110		122	128		106
102	125		112	119	119	118	110	117	123	111	108	47. Sowing		108			124	126	132	124		123	128		109
200		187	192	178		213	182	182		159	182	48. Hay Cutting					210	185		217		196	206		195
218	227	213	210	215	228	222	210	214	222	202	180	49. Grain Cutting			234		225	222	230	230	222	229	229		217
144		130	135	130		133	121	122		122	135	50. Potato Planting					140	135		144		140	144		

Phenological Observations, Canada, 1921

Year 1921

Day of year corresponding to last day of each month

January	31	July	212
February	59	August	243
March	90	September	273
April	120	October	304
May	151	November	334
June	181	December	365

Observation		When first seen										When becoming common									
		Ninette, Man.	Oakbank, Man.	Treherne, Man.	Cape Croker, Ont.	Perth, Ont.	Rutherglen, Ont.	Toronto, Ont.	Abitibi, Que.	Lennoxville, Que.	Scotch Lake, N.B.	Ninette, Man.	Oakbank, Man.	Treherne, Man.	Cape Croker, Ont.	Perth, Ont.	Rutherglen, Ont.	Toronto, Ont.	Abitibi, Que.	Lennoxville, Que.	Scotch Lake, N.B.
1. Alder (Alnus incana)	Shedding pollen					84		83	132	87	104					85		91	132		
2. Canada Thistle (Cirsium arvense)	Flowering	179				180				171	190					182					
3. Trailing Arbutus (Epigaea repens)	"						121	99			115							108			124
4. Dandelion (Taraxacum officinale)	"		135	125	103	114	120	102	139	103	124				114	118		121		110	126
5. Violet, Blue (Viola palmata cucullata)	"	142	143		93	114		116		121	121				121	114		124		130	124
6. Violet, White (Viola blanda)	"	137				114	119	116			117					114		122			
7. Columbine (Aquilegia)	"				133	127		148		121	173					128		150		126	
8. Trees appear green		150			97	120		121	134	133	121				116	120					
9. Red Clover (Trifolium pratense)	Flowering		143		154	147		151		153	153				161	150		157		159	
10. White Clover (Trifolium repens)	"	156	165		150	143		148		166	153				161	149		154		175	
11. Wild Raspberry (Rubus strigosus)	"					147		140		155	177					155		143		161	
12. Cultivated Currant (Ribes rubrum)	"					123		124		119	135					123		126		125	
13. Wild Rose (Rosa)	"	161	161		148	150		156			171		167			150		161			
14. Trillium (Trillium)	"					148		116		116	121				112	150		126		120	126
15. Anemone (Anemone)	"			100		146		126		123	133					156		126		130	
16. Maple (Acer)	"							77		82	113							80			
17. Strawberry Wild (Fragaria Virginiana)		145	149	140	103	114	122	114	142	121	117				115	118		121		125	127
18. Strawberry Wild (Fragaria Virginiana)	Fruit ripe				147	147		152		177	167				167	160		159		181	
19. Crocus, Cultivated (Crocus)	Flowering				93	95		91		98	102				97	98		96		105	106
20. Lilac (Syringa vulgaris)	"	153	156		137	127	141	130		136			156		143	131		133		140	
21. Apple (Pyrus malus)	"				125	124	139	128		127	142				135	126		132		132	147
22. Plum, Cultivated (Prunus domestica)	"		139	146	124		124	123		123	132				131			131		126	
23. Cherry, Wild (Prunus)	"	141	141			131		119		136	136					132		121		140	
24. Cherry, Cultivated (Prunus cerasus)	"			142	119		125	120		126					124			125		132	

			118	139	148	146		142	147			25. Buttercup (Ranunculus acris).................... "			124	142	150	145	
				157	123	153		167	163			26. Yellow Pond Lilly (Nuphar advena).............. "				159	158	171	
	153			147		157		154	164			27. Blue-eyed Grass (Sisyrinchium).......... "				147	157	171	
138	141							118				28. Saskatoon (Amalanchier Canadensis).............. "						120	
				187				226	201			29. Golden Rod (Solidago)............... "				189		237	
92		107	76	70	114		96	131				30. Wild Geese..			114	70			
95			76	70			96	60	93			31. Wild Ducks..				70			
93		97	70	59		68	97	68	80			32. Robins (Turdus Migratorius)..............................			85	71	79	74	
78		93	80	77		68		87				33. Meadow Larks (Sturnella).......................			86	77	89	96	
		99	71	58		68		71	122			34. Blue Birds (Sialia sialis)..............................			85	71	78	79	
81						94	95		104			35. Flickers or Golden Woodpeckers (Colaptes auratus).........				96	97		
		98	78	60		63		80	83			36. Song Sparrows (Melospiza fasciata).......................			88	71	79	84	
133			96	139		112	125	111	113			37. Swallows (Clivicola riparia).............................				139	151	120	
78		94		60					69			38. Juncoes (Junco hyemalis)................................				60	91		
118		141		128		136		141				39. Orioles (Icterus galbula)...............................			135	133	142	145	
145			125	139		141	116	141	151			40. King Birds (Tyrannus tyrannus)...........................				142	150	142	
		144	133	139	140	144		159	141			41. Humming Birds (Trochilus colubris).......................			140	142		167	
	108		79	91	95	84	116	87	99			42. Frogs Piping..				96	90	63	101
			80	78		78	140	102	112			43. Earth Worm Casts (frost out of ground).....................				81	91	106	
115		75	77	86			118		105			44. Lakes Open..							
				73		69	105	70	86			45. Rivers Open..							
105	94		79	111	109	95	130	96	106			46. Ploughing...			97	111	102	102	
117		108	97	125	118	95	152	110	120			47. Sowing..			102	125	116	126	125
	189		164	162		176	213	172	189			48. Hay Cutting...				182		182	
	244			197				207	211			49. Grain Cutting...				197		218	
	145		115	122		105	152	136	135			50. Potato Planting...			143	144	120	140	

PHENOLOGICAL OBSERVATIONS, CANADA, 1921

YEAR 1921

Day of the year corresponding to the last day of each month

Jan.	31	July	212
February	59	August	243
March	90	September	273
April	120	October	304
May	151	November	334
June	181	December	365

When first seen

	I. Yarmouth & Digby Counties, N.S.	II. Shel., Queens & Lun. Counties, N.S.	III. Annapolis & Kings Counties, N.S.	IV. Hants & Colchester Counties, N.S.	V. Halifax & Guysboro Counties, N.S.	VIA. Chignecto & Cobequid Slopes, N.S.	VIB. Chignecto & Cobequid Slopes, N.S.	VII. Northumberland Sts. Slope, N.S.	VIII. Rich. & Cape Breton Cos., N.S.	IX. & X. Bras d'Or & Inv. Slope, N.S.	Average Dates
1. Alder (Alnus incana, Wild)	90	89	101	106	105	110	130	107	106	113	106
2. Aspen (Populus tremuloides)	105	124	107	118	97		123	123	117	118	115
3. May Flower (Epigaea repens, L.)	88	94	93	101	103	105	103	106	111	111	102
4. Field Horsetail (Equisetum arvense)	99	121	117	121	122	111	120	122	128	120	118
5. Blood Root (Sanguinaria Canadensis)	112	148		123	125		125	120	127	127	126
6. White Violet (Viola Blanda)	111	114	116	119	118	117	117	119	122	123	118
7. Blue Violet (Viola palmata, *cucullata*)	115	121	119	122	125	119	123	124	129	125	123
8. Hepatica (Hepatica triloba, etc.)	130	123	120	122	124			126		115	123
9. Red Maple (Acer rubrum)	113	118	115	123	129			123	131	120	122
10. Strawberry (Fragaria Virginiana)	112	120	116	121	123	120	122	121	124	124	120
11. Strawberry (Fragaria Virginiana) Fruit ripe	152	150	156	154	161	157	158	156	164	151	153
12. Dandelion (Taraxacum officinale)	117	124	122	124	127	123	127	128	131	126	125
13. Adder's Tongue (Erythronium Americanum)	118	124	131	131	141	129	123	119			127
14. Gold Thread (Coptis trifolia)	120	121	129	129	131	128	133	131	133	132	129
15. Spring Beauty (Claytonia Caroliniana)			120	121	128	122	124	123	123	117	122
16. Ground Ivy (Nepeta Glechoma)	132	133	129	132	135	129	122	140	141	140	133
17. Indian Pear (Amelanchier Canadensis)	120	132	125	133	137	134	134	134	143	139	133
18. Indian Pear (Amelanchier Canadensis) Fruit ripe				159				178	201		179
19. Wild Red Cherry (Prunus Pennsylvanica)	121	137	134	138	145	139	131	138	151	140	138
20. Wild Red Cherry (Prunus Pennsylvanica) Fruit ripe		178							220		199
21. Blackberry (Vaccinium Can. and Penn)	119	133	134	136	136	142	136	139	150	151	138
22. Blackberry (Vaccinium Can and Penn.) Fruit ripe				235				222	209		222
23. Buttercup (Ranunculus acris)	123	141	142	146	151	144	148	147	155	154	145
24. Tall Buttercup (R. Repens)	147	146	147	151	154	152	155	155	161	161	153
25. Creeping Buttercup (Tril. erythrocarpum)	136	138	135	145	144	139	137	141	148	146	141
26. Rhodora (Rhododendron Rhodora)	128	138	137	143	143	142	143	148	151	153	143

When becoming common

	Average Dates	I. Yarmouth & Digby Counties, N.S.	II. Shel., Queens & Lun. Counties, N.S.	III. Annapolis & Kings Counties, N.S.	IV. Hants & Colchester Counties, N.S.	V. Halifax & Guysboro Counties, N.S.	VIA. Chignecto & Cobequid Slopes, N.S.	VIB. Chignecto & Cobequid Slopes, N.S.	VII. Northumberland Sts. Slope, N.S.	VIII. Rich. & Cape Breton Cos., N.S.	IX. & X. Bras d'Or & Inv. Slope, N.S.
1. Alder (Alnus incana, Wild)	110	102	98	112	113	112	115		111	110	119
2. Aspen (Populus tremuloides)	121	112	127	116	127	105		127	130	122	122
3. May Flower (Epigaea repens, L.)	102	103	105	105	115	111	114	112	114	117	119
4. Field Horsetail (Equisetum arvense)	124	109	127	120	126	126	117	127	126	133	128
5. Blood Root (Sanguinaria Canadensis)	131	115	151		128	128		131	125	133	140
6. White Violet (Viola Blanda)	123	118	123	121	126	124	122	120	123	127	128
7. Blue Violet (Viola palmata, *cucullata*)	128	122	126	125	128	130	126	127	129	133	130
8. Hepatica (Hepatica triloba, etc.)	137	181	130	130	130	128			129		134
9. Red Maple (Acer rubrum)	127	128	124	122	128	134	120		128	135	127
10. Strawberry (Fragaria Virginiana)	128	121	128	124	131	132	126	131	128	130	132
11. Strawberry (Fragaria Virginiana) Fruit ripe	167	168	167	165	164	170	162	168	164	173	169
12. Dandelion (Taraxacum officinale)	132	127	130	128	132	131	130	133	133	135	140
13. Adder's Tongue (Erythronium Americanum)	137	136	133	153	134	145	135	132	124		
14. Gold Thread (Coptis trifolia)	132	123	132	133	126	133	122	138	136	138	138
15. Spring Beauty (Claytonia Caroliniana)	130			125	126	138	126	148	128	126	125
16. Ground Ivy (Nepeta Glechoma)	139	133	138	136	140	142	140	128	144	146	144
17. Indian Pear (Amelanchier Canadensis)	138	128	136	130	138	141	135	139	138	147	147
18. Indian Pear (Amelanchier Canadensis) Fruit ripe	210									210	
19. Wild Red Cherry (Prunus Pennsylvanica)	144	135	142	139	148	147	143	140	141	155	145
20. Wild Red Cherry (Prunus Pennsylvanica) Fruit ripe	203		178							228	
21. Blackberry (Vaccinium Can. and Penn)	145	132	141	140	141	144	150	142	144	154	158
22. Blackberry (Vaccinium Can and Penn.) Fruit ripe	227				235					219	
23. Buttercup (Ranunculus acris)	154	148	149	148	155	156	153	154	153	161	158
24. Tall Buttercup (R. Repens)	159	152	153	152	158	169	157	158	161	165	166
25. Creeping Buttercup (Tril. erythrocarpum)	148	144	150	142	149	150	142	147	147	151	154
26. Rhodora (Rhododendron Rhodora)	148	137	145	143	148	148	145	147	153	155	160

133	146	142	146	151	147	153	146	151	153	147	27. Pigeon Berry (Cornus Canadensis)	152	144	152	146	153	156	150	156	150	156	157
	170							221		195	28. Pigeon Berry (Cornus Canadensis) Fruit ripe	205		178							233	
135	143	137	143	147	147	143	141	150	148	143	29. Star Flower (Trientalis Amercana)	150	145	150	145	148	152	148	152	146	155	155
141	147	146	152	155	150	159	153	160	145	151	30. Clintonia (Clintonia borealis)	166	145	152	154	156	156	153		156	165	152
	142	150	154	164	162		150	164	158	156	31. Marsh Calla (Calla palustris)	159		148	152	158	170			152	168	162
143	149	148	154	153	150	147	157	162	157	152	32. Lady's Slipper (Cypripedium acaule)	158	150	155	153	158	159	162	154	161	167	163
145	149	145	149	156	151	153	153	161	158	152	33. Blue-Eyed Grass (Sisyrinchium angustifol)	156	151	155	148	155	160	152	159	153	166	163
156	157	148	159	160	165	167	163	167	160	160	34. Twin Flower (Linnaea borealis)	164	163	163	157	156	165	163	171	168	173	157
143	153	147	146	144	147	139	155	157	150	148	35. Pale Laurel (Kalmia glauca)	152	148	158	151	151	153	153	140	156	161	150
147	159	154	154	160	163	142	152	174	154	156	36. Lambkill (Kalmia augustifolia)	163	154	166	159	163	169	168	148	158	178	163
149	146	149	152	160	160	153	157	160		154	37. English Hawthorne (Crataegus oxyacantha)	159	154	153	151	158	167	165		159	165	157
164	152	147	149	157			152	161	152	154	38. Scarlet Fruited Thorn (Crataegus coccinea, etc.)	161	170	158	152	154	161			157	167	168
154	165	155	159	165	162	157	162	168	168	162	39. Blue Flag (Iris versicolor)	167	162	169	164	164	170	165	162	165	172	163
151	156	153	158	164	161	159	157	163	157	158	40. Ox-eye Daisy (Chrysanthemum Leucanth)	165	161	162	160	168	167	166	166	163	169	165
156	160	155	157	163	160	159	160	165	159	159	41. Yellow Pond Lilly (Nuphar advena)	164	161	165	163	164	167	168	164	165	171	156
144	153	150	154	160	162	160	149	162	149	154	42. Raspberry (Rubus strigosus)	162	157	162	156	162	165	168	166	152	168	162
		134		164				204	176	169	43. Raspberry (Rubus strigosus) Fruit ripe	184					165			197	213	160
152	163	164	165	171	171		170	171	160	165	44. Yellow Rattle (Rhinanthus Crista-galli)	170	161	169	173	170	167	174		173	175	165
149	160	158	161	163	172	163	160	170	169	163	45. High Blackberry (Rubus villosus)	168	165	168	164	167	169	172	170	165	174	
								239		239	46. High Blackberry (Rubus villosus) Fruit ripe	247				243					251	
162	167	166	161	170		161	168		165	165	47. Pitcher Plant (Sarracenia purpurea)	170	167	171	170	165	174		164	174		173
162	170	159	170	172	165		165	170	172	167	48. Heal-All (Brunella vulgaris)	172	169	175	163	175	176	170		170	174	174
169	171	161	168	165	169		171		172	168	49. Common Wild Rose (Rosa lucida)	174	177	176	171	178	174	173		174		172
155	157	162	166	167	159	164	163	170	163	163	50. Fall Dandelion (Leontodon autumnale)	169	161	165	168	174	171	166	172	166	174	168
	164	156	159	176	178	130	157	167	158	160	51. Butter and Eggs (Linaria vulgaris)	160		169	165	170			146	130	173	162
119	130	123	125	131	123	123	128	137	132	127	52. Expanding Leaves (Trees appear green)	140	134	141	133	137	147	137	150	137	146	142
128	134	132	140	147	145	146	138	147	150	141	53. Red Currant (Ribes rubrum) (cultivated)	144	132	142	137	146	150	151	137	144	152	150
		181	168							175	54. Red Currant (Ribes rubrum) Fruit ripe	178			181	174						

PHENOLOGICAL OBSERVATIONS, CANADA, 1921

YEAR 1921

Day of the year corresponding to the last day of each month

Month	Day	Month	Day
January	31	July	212
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When first seen

	I. Yarmouth & Digby Counties, N.S.	II. Shel. Queens & Lun. Counties, N.S.	III. Annapolis & Kings Counties, N.S.	IV. Hants & Colchester Counties, N.S.	V. Halifax & Guysboro Counties, N.S.	VIA. Chignecto & Cobequid Slopes N.S.	VIB Chignecto & Cobequid Slopes, N.S.	VII. Northumberland Sts. Slope, N.S.	VIII. Rich. & Cape Breton Cos., N.S.	IX & X. Bras d'Or & Inv. Slope, N.S.	Average Dates
55. Black Currant (R. nigrum) (cultivated)	127	136	138	142	145	147	149	133	149	150	143
56. Black Currant (R. nigrum) Fruit ripe		177									177
57. Cherry (Prunus Cerasus)	129	140	133	142	148	147	145	140	153	147	142
58. Cherry (Prunus Cerasus) Fruit ripe		178	176	176							177
59. Plum (Prunus domestica)	130	140	134	139	149	152	146	139	155	147	143
60. Apple (Pyrus Malus)	132	141	135	143	147	142	141	142	153	149	142
61. Lilac (Syringa vulgaris)	141	149	146	148	154	151	152	149	162	151	150
62. White Clover (Trifolium repens)	150	153	153	156	158	154	159	156	160	157	156
63. Red Clover (Trifolium pratense)	139	147	149	154	158	158	159	156	160	159	154
64. Timothy (Phleum pratense)	153	148	160	168	163	152	168	171		166	161
65. Potato (Solanum tuberosum)	172	172	171	169	164						170
66. Ploughing first of season	91	106	110	124	117	115	115	121	114	111	112
67. Sowing	103	122	125	133	122	129	124	131	130	127	125
68. Potato-planting	107	116	128	138	125	129	140	134	125	128	127
69. Sheep-shearing	120	119	123	142	132	124	138	140	118	123	128
70. Hay-cutting	175	191							204		190
71. Grain-cutting		204		246				235	227		228
72. Potato-digging		264	262	253				265	267		262
73a. Opening of rivers	68	81	79	89	80	69	60	74	85	124	81
73b. Opening of lakes	70	87	92	92	107	8		78	109	104	92
74a. Last snow to whiten ground	95	116	118	105	120	119	110	116	105	120	112
74b. Last snow to fly in air	108	132	125	125	131	137	116	130	130	131	127
75a. Last spring frost—hard	121	121	125	127	170	130		140	119	122	131
75b. Last spring frost—hoar	103		134	142	130			154	168		138
76a. Water in streams—high		77	85	107	72		99		102	69	89

When becoming common

	Average Dates	I. Yarmouth & Digby Counties, N.S.	II. Shel., Queens & Lun. Counties, N.S.	III. Annapolis & Kings Counties, N.S.	IV. Hants & Colchester Counties, N.S.	V. Halifax & Guysboro Counties, N.S.	VIA. Chignecto & Cobequid Slopes, N.S.	VIB. Chignecto & Cobequid Slopes, N.S.	VII. Northumberland Sts. Slope, N.S.	VIII. Rich. & Cape Breton Cos., N.S.	XI & X. Bras d'Or & Inv. Slope, N.S.
55. Black Currant (R. nigrum) (cultivated)	148	131	141	141	147	149	152	160	145	155	154
56. Black Currant (R. nigrum) Fruit ripe	177		177								
57. Cherry (Prunus Cerasus)	148	139	145	137	144	157	151	152	145	159	150
58. Cherry (Prunus Cerasus) Fruit ripe	182		178	189	178						
59. Plum (Prunus domestica)	149	140	147	139	144	152	157	155	146	160	149
60. Apple (Pyrus Malus)	148	142	147	141	148	153	146	147	147	159	153
61. Lilac (Syringa vulgaris)	156	149	156	151	157	160	156	155	154	166	155
62. White Clover (Trifolium repens)	161	156	161	159	162	164	160	163	162	166	160
63. Red Clover (Trifolium pratense)	160	146	156	153	161	164	163	165	162	166	165
64. Timothy (Phleum pratense)	168	162	155	170	170	167		175	172		169
65. Potato (Solanum tuberosum)	173	181	163	172		169					178
66. Ploughing first of season	127	109	118	122	130	123	122	166	131	121	125
67. Sowing	132	117	127	132	141	131	128	135	139	138	130
68. Potato-planting	136	122	127	139	148	136	136	145	143	132	135
69. Sheep-shearing	139	142	135	129	147	141	135	141	150	130	135
70. Hay-cutting	196	181								211	
71. Grain-cutting	236									236	
72. Potato-digging	278									278	
73a. Opening of rivers											
73b. Opening of lakes											
74a. Last snow to whiten ground											
74b. Last snow to fly in air											
75a. Last spring frost—hard											
75b. Last spring frost—hoar											
76a. Water in streams—high											

								249		249	76b.	Water in streams—low	
263	253	233					290	237		255	77a.	First autumn frost, hoar	
313	297	263	299				290	307		295	77b.	First autumn frost—hard	
298	299	286					298	297		296	78a.	First snow to fly in air	
311	312	311					303	315		310	78b.	First snow to whiten ground	
329	322	331					355	329		333	79a.	Closing of lakes	
343	311	334						355		336	79b.	Closing of rivers	
79	79	82	81	71		79	77	81	84	79	81a.	Wild ducks migrating, N	
	293	287	332					296		302	81b.	Wild ducks migrating, S	
84	77	77	76	75	74	75	77	77	90	78	82a.	Wild geese migrating, N	
	300	286	322				305	298		302	82b.	Wild geese migrating S	
81	74	83	87	88	88	109	81	84	81	86	83.	Song Sparrow (Melospiza fasciata, North)	
69	77	70	73	72	72	78	73	71	76	73	84.	Robin (Turdus migratorius)	migrating
70	83	76	84	71	80	89	88	87	118	85	85.	Junco (Junco hiemalis)	"
94	111	97	118	129	106		130	120	122	114	86.	Spotted Sandpiper (Actitis macularia)	"
138	112	98	122	130			136		99	133	87.	Meadow Lark (Sturnella magna)	"
100	130	128	126	121	106		131	123	139	134	88.	Kingfisher (Ceryle Alcyon)	"
107	107	120	134	130	109		130	122	136	121	89.	Myrtle Warbler (Dendroeca coronata)	"
123	135	135	138	130		151	141	141	160	139	90.	Yellow Warbler (D. aestiva)	"
79	105	127	127	128		128	116	124	106	116	91.	White-throated Warbler (Zonotrichia alba)	"
144	150	143	142	144	145	147	139	151	161	147	92.	Humming Bird (Trochilus colubris)	"
	136	123	137	140	145	140	137	146		138	93.	King Bird (Tyrannus Carolinensis)	"
	147	133	137	141	161		136	137	140	142	94.	Bobolink (Dolychonyx oryzivorus)	"
137	146	139	135	130	165		131	145	142	141	95.	American Goldfinch (Spinis tristis)	"
142	161	124	143				138	143	150	143	96.	American Redstart (Setophaga ruticilla)	"
136	140	151	151	135	125		129			138	97.	Cedar Waxwing (Ampelis cedrorum)	"
88	115	128	129	129	108	158	114	152	126	125	98.	Night Hawk (Chordeiles Virginianus)	
82	93	90	94	100	104	105	100	103	103	97	99.	First piping of frogs	
94	102	111	113	106	114	102	114	111	115	108	100.	First appearance, snakes	

Mémoires de la Société Royale du Canada
SECTION I

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M. Louis-Raymond Giroux
(1841-1911)

Par l'honorable L.-A. PRUD'HOMME, M.R.S.C.

(Lu à la réunion de mai 1922)

I

M. Giroux naquit le 4 juillet 1841 à Sainte-Geneviève (Berthier en Haut), province de Québec, du mariage de Louis Giroux et de Scolastique Pelland. C'est au sein d'une famille, profondément religieuse, qu'il puisa la foi ardente et le sentiment du devoir qui devaient le distinguer dans toute sa carrière sacerdotale. Son âme y respira, comme dans un sanctuaire, la bonne odeur des vertus domestiques; ce fut dans ce milieu qu'elle y reçut sa première trempe. L'influence du foyer est souvent décisive pour toute la vie. Elle a une répercussion à laquelle un enfant échappe difficilement. On y trouve l'explication du fait que le clergé s'est surtout recruté parmi les familles de nos *habitants*, à la foi robuste et aux mœurs austères et qu'il en fut ainsi également de nos grands hommes d'État.

M. Giroux commença par fréquenter l'école de son village. Le curé de la paroisse natale de M. Giroux était M. Jean François Régis Gagnon, qui mourut à Berthier en 1875. Il ne tarda pas à remarquer chez ce jeune élève, les germes d'une vocation sacerdotale. Depuis lors, il l'entoura d'une protection spéciale, et, après ces études préliminaires, il décida ses parents à l'envoyer au collège de Montréal, afin de seconder les vues de la Providence qui semblaient l'appeler au sacerdoce.

On sait que les Messieurs de Saint-Sulpice qui dirigent cette institution avec un dévouement admirable se proposent surtout de préparer des Lévites au Seigneur. M. Giroux y reçut une culture intellectuelle supérieure. A la retraite des finissants, après ses huit années d'étude, son directeur spirituel lui déclara qu'il n'avait pas à hésiter, que Dieu l'appelait au service de ses autels et à la conquête des âmes.

Pendant son cours classique, il s'était lié d'étroite amitié avec le R. P. Allard, O.M.I., le Juge Dubuc et le célèbre Louis Riel. Il devait les retrouver plus tard à la Rivière Rouge.

Après avoir pris la soutane, il fut quelque temps surveillant à l'école normale Jacques-Cartier, puis il entra au grand séminaire où il poursuivit et termina ses études théologiques.

Il conserva toujours une grande affection et une gratitude profonde pour son Alma Mater et les professeurs distingués qui l'avaient formé au ministère. Lorsqu'il avait la bonne fortune de rencontrer à Sainte-Anne, un ancien élève du collège de Montréal, il aimait à rappeler le nom de ses anciens professeurs et à faire l'éloge de leur science et de leur vertu. Lorsque parfois des questions de morale inquiétaient sa conscience, il recourait aux lumieres de Monsieur l'abbé Rouxel, P.S.S. casuiste remarquable, d'une autorité reconnue dans tout le pays.

En 1868, Monseigneur Taché avait député l'abbé J. N. Ritchot dans la province de Québec pour y recruter quelques prêtres. Ce dernier passa l'hiver dans cette province. Il se rendit au grand séminaire de Montréal, pour sonder le terrain et eut une longue entrevue avec M. Giroux. Il promit à M. Ritchot qu'il lui écrirait bientôt sa décision. Au printemps de 1868, il lui répondit qu'il acceptait.

Dans la vie de Monseigneur Taché, par Dom Benoît (vol. 1, p. 586), l'auteur en quelques mots fait ainsi l'éloge de M. Giroux: "Ce fut le seul sujet que M. Ritchot put recruter, mais celui qui se donnait à l'archidiocèse de Saint-Boniface, par son énergie et son zèle apostolique valait une légion."

Il fallait à cette époque, un dévouement peu ordinaire pour quitter parents, amis, et patrie et aller ensevelir son existence sur les confins de la sauvagerie. Ces ouvriers de la première heure ont droit à ce que leurs noms soient entourés de notre respectueuse gratitude et de notre affectueux souvenir.

M. Giroux aurait préferé attendre au mois de juin pour son ordination, mais M. Ritchot se préparâit à partir dès les premièrs jours de ce mois. C'est pourquoi il dut consentir à devenir prêtre plus tot qu'il ne se proposait. Il fut ordonné par Monseigneur Grandin, évêque de Saint-Albert le 24 mai 1868 et partit de Montréal le 2 juin, ayant pour compagnon M. Ritchot.

Le trajet se fit par chemin de fer jusqu'à Saint-Cloud et de là en charrette jusqu'à Saint-Boniface où il arriva le 7 juillet 1868.

II

Monseigneur Taché avait l'habitude de retenir auprès de lui les nouveaux prêtres afin de les préparer aux coutumes du pays et de les initier au ministère des missions naissantes. C'est ce qu'il fit avec M. Giroux. De plus la chaire de philosophie étant sans titulaire au collége de Saint-Boniface, il le désigna à ce poste.

Si les murs du vieux collège pouvaient parler, que de souvenirs touchants, ils nous rediraient. Je n'en évoquerai qu'un seul.

En 1852 lorsqu' une incendie réduisit en ruine une partie considérable de Montréal, Monseigneur Bourget au lendemain de ce désastre eut une pensée sublime. S'adressant aux fidèles, il les exhorta tout d'abord à apaiser le courroux de Dieu et à implorer son secours. Remuez les cendres de vos maisons détruites, leur disait il, vous y trouverez encore quelques sous et offrez les pour les missions de la Rivière Rouge. Dieu vous les rendra au centuple. En effet une souscription fut aussitot organisée et c'est avec le produit de cette aumone que fut construit l'ancien collège de St. Boniface où M. Giroux allait enseigner. Cette maison est un monument qui redit sans cesse la grande générosité des catholiques de Montréal. Lorsque le nouveau collège fut terminé en 1880, l'ancienne batisse fut convertie en salle municipale et bureau d'enregistrement. Elle est devenue depuis le Monastère des Soeurs Carmélites.

La même année, M. Giroux fut également chargé d'aller dire la messe, tous les jeudis, à Saint-Vital, dans une chapelle voisine de la résidence de la famille Riel. De plus, une fois par mois, il partait le samedi pour "La grande pointe des Chênes" deveune depuis Saint-Anne des chênes, pour revenir le lundi suivant.

Le 25 décembre 1868, il vint y chanter la messe de minuit dans la chapelle construite par le P. Lefloch, O.M.I. Ce fut sa première visite à Sainte-Anne, qui devait être son heritage pendant 43 ans.

L'année suivante (1869) il fut nommé directeur du collège, tout en restant attaché à la desserte de ces deux missions. Ses qualités aimables lui gagnèrent bientot l'affection et des élèves et de la population qu'il visitait. Il hérita de son premier pasteur, Monseigneur Taché, d'une tendresse particulière pour les anciens du pays.

Ces derniers savaient qu'il les aimait comme ses fils aînés dans la foi. Il se plaisait dans leur commerce et il acquit bientot parmi eux une grande influence.

Lorsque Louis Riel eut organisé un gouvernement provisoire et qu'il eut établi le siège de son conceil au Fort Garry, il demanda à l'administrateur du diocèse, en l'absence de Monseigneur Taché retenu à Rome par le concile occuménique, de lui donner un chapelain pour la garnison du fort. M. Giroux, confrère de collège de Riel et son ami intime, était tout désigné pour ce poste. Grâce à son tact exquis et à la douceur de son caractère, il s'acquitta de cette tâche avec un rare bonheur. Il couvient de rappeler ici que le gouvernement de Riel était légitime et constitutionnel. En 1869, la compagnie de la Baie d'Hudson qui gouvernait le pays en vertu de sa charte, avait retrocédé tous ses droits à la couronne et le gouverneur McTavish avait formellement abdiqué ses fonctions. Le pays se trouvait sans autorité établie pour maintenir l'ordre et protéger la liberté des citoyens. Dans semblable occurrence, c'est le droit des citoyens de former un gouvernement de nécessité. Blackstone le proclame en propres termes dans ses Commentaires. Salus populi, suprema lex. Ces gouvernements *de facto* deviennent ainsi des gouvernements *de jure*, qui sont révêtus de l'autorité Souveraine et ont droit au respect et à l'obéissance de leurs décrets.

M. Giroux était donc le chapelain d'un Président et d'un gouvernement régulier et investi de tous les pouvoirs nécessaires pour maintenir l'ordre dans la colonie. Les Métis n'oublièrent jamais les services qu'il leur rendit à cette époque troublée où la guerre civile faillit plus d'une fois couvrir le pays de ruine et de sang. On comprend facilement que la dignité sacerdotale du chapelain servait d'appui au nouveau gouvernement parfois ébranlé par un groupe d'agitateurs. De plus, Riel avait eu la sagesse de rallier autour de lui les hommes les plus en vue de l'élément français et anglais et c'est ainsi qu'il put sauver la situation.

On sait qu'au mois d'aout 1870, après l'arrivée de Wolseley au Fort Garry le gouvernement provisoire prit fin.

Le 1er Septembre de la même année (1870) Monseigneur Taché nommait M. Giroux prêtre desservant avec résidence à Sainte-Anne où il exercait deja le ministère à des dates intermittentes depuis près de deux ans.

Quels furent les commencements de Sainte-Anne des Chênes? Les premiers habitants de cet endroit que nous connaissons furent les Sauteux.

Ils y avaient construit des loges à l'entrée du bois et y vivaient de chasse. Sans doute, les Métis y firent des expéditions de chasse de temps à autre, à l'automne. Cependant ce n'est qu'en 1856, qu'on constate la présence de colons fixés à Sainte Anne.

D'après une note du "Codex historicus" tenu par M. Giroux les premiers colons de Sainte Anne furent M.M. Jean Baptiste Perreault (dit Morin) père et fils, Basile Larence, Théophile Grouette, Jean Racine, John Porter, Onésime Manseau, Jean Baptiste Lemyre, Jean-Baptiste Valiquette, Francis Nolin, Jean Baptiste Desautels (dit Lapointe), Norbert Perreault et Jean Baptiste Grouette.

Jean Baptiste Desautels hiverna à Lorette en 1868. En mai 1869 il alla se fixer à Sainte Anne, à la coulée des sources. Il y construisit un moulin à scie à un endroit où les castors avaient fait une chaussée considérable. Il acheta sa terre du chef des Sauteux "Les grandes oreilles" et lui donna comme prix d'achat quelques sacs de farine, quelques pains et un chapelet.

"Pour rester ici, lui dit le chef, il faut que tu sois parent avec nous. Quelle parenté veux-tu prendre?

—Frère en Jesus-Christ lui répondit M. Desautels.

—Ca bon, dit le chef, on va t'appeler Frère."

Durant l'hiver de 1858, à l'occasion d'un accident qui coûta la vie à un enfant de Basile Larence, le P. Simonet O.M.I., se rendit à Sainte-Anne. Il fut le premier prêtre à célébrer la Sainte Messe à cet endroit.

En 1859, Monseigneur Taché chargea le P. Lefloch O.M.I. alors desservant de la cathédrale de Saint-Boniface de visiter cet établissement. Une fois par mois les habitants de la Grande Pointe des Chênes venaient chercher et ramener le P. Lefloch. Le bon père Morin (Jean Baptiste Perreault dit Morin) comme ou l'appelait alors, donnait toujours au missionnaire une cordiale hospitalité. C'est dans sa maison qu'il disait la Sainte-Messe et remplissait les divers offices de son ministère.

Lorsqu'il y eut un prêtre résident, jamais Monseigneur Taché, dont le coeur était si bon et si reconnaissant, ne venait à Sainte-Anne, sans rendre visite à cet excellent Canadien pour lui témoigner sa gratitude de la généreuse hospitalité qu'il avait donnée au prêtre.

Le P. Lefloch était originaire de la Bretagne et dévot serviteur de sainte Anne. Mgr. Provencher avait manifesté souvent le désir de donner le nom de cette illustre thaumaturge à l'une des missions. Monseigneur Taché de concert avec le P. Lefloch fut heureux de mettre cette nouvelle mission sous la protection de la bonne sainte Anne, et de realiser les souhaits de son prédecesseur qui répondaient si bien à sa tendre dévotion.

Ce ne fut qu'après l'inondation de 1861, que l'établissement commerça à se développer. Plusieurs cultivateurs de Saint Boniface, redoutant le retour de l'eau haute, décidérent de prendre des terres à Sainte-Anne. La maison du père Morin devint bientôt trop petite pour la population. Durant l'été de 1864 le P. Lefloch construisit une chapelle dans le jardin du P. Morin (lot 19). Elle avait environ 30 pieds de longueur et 15 pieds de largeur et avait été construite en pièces d'épinette équarries. M. Giroux y ajouta une petite sacristie en arrière. Parfois il était impossible au P. Lefloch de visiter Sainte Anne, alors les PP. Lestane, Tissol et St. Germain le remplaçaient.

En 1869, le P. Tissol y séjourna plus d'un mois pour faire le catéchisme et préparer les enfants à leur première communion, parce-que M. Giroux Directeur du collège ne pouvait s'absenter pour un temps aussi considerable.

Quoiqu'il en soit ce qu'il faut retenir c'est que depuis l'automne 1868, M. Giroux etait le missionnaire chargé de l'établissement de la grande Pointe des Chénes.

III

En 1868, les sauterelles ruinèrent la moisson. Elles dévorèrent jusqu'à l'herbe. Ce fut un désastre pour la colonie. Monseigneur Taché fit appel à la charité publique. Des bateaux chargés de provision descendirent la Rivière Rouge du fort Abercrombie jusqu'au Fort Garry. Le transport par voie américaine offrait cependant des inconvénients. Le gouvernement canadien qui s'occupait dejà activement d'annexer tout l'ouest à la confédération crut l'occasion favorable à ses desseins. Il résolut de dépenser des sommes considérables dans la colonie pour aider à la population et disposer les esprits au changement projeté.

Il décida d'ouvrir une voie de communication à travers la foret eutre le lac des Bois et la Rivière Rouge. A l'automne de 1868, un arpenteur du nom de Snow arrivait dans le pays avec un certain nombre d'hommes recrutés dans Ontario. Il commença les travaux à la lisière de la foret, près de la terre de Jean-Baptiste Desautels. Il ne tarda pas à mécontenter les gens du pays par le maigre salaire qu'il offrait. Il obligeait ceux qui consentaient à travailler pour ces prix minimes, à être payés en effets pris dans un magasin d'un homme qui était tenu pour un membre odieux du parti Canadien. Les Métis, tout en murmurant se soumirent à ces exigences à cause de la grande détresse dans laquelle ils se trouvaient, cette année là. Pendant l'hiver, les esprits commencèrent à se soulever contre Snow. On avait appris par des lettres perdues par Snow, qu'il avait fait des traités avec les Sauteux pour l'achat de leurs terres pour son propre compte et celui de ses engagés d'Ontario. On répétait de plus, qu'on avait enivré les sauvages afin d'obtenir plus facilement la cession de leur territoire de chasse. Mais ce qui porta l'indignation à son comble fut la nouvelle qu'un des compagnons de Snow avait publié dans les journaux d'Ontario des correspondances dans lesquelles il insultait la population française et anglaise du pays et surtout les Métis. Les gens du pays se soulevèrent contre les arpenteurs. Ils se rendirent auprès de Snow et le forcèrent d'abandonner les lieux.

Ce fut leur premier coup de main, d'où devait sortir l'année suivante, le gouvernement provisoire.

Quelques jours après, Snow fut condamné par les tribunaux, pour avoir vendu des liquers enivrantes aux sauvages.

Durant l'été de 1869, Snow put continuer ses arpentages sur le chemin Dawson, avec un plus grand nombre d'engagés d'Ontario qui affichaient un profond mépris pour les Métis.

A environ trois milles à l'est de l'église de Sainte Anne du coté sud de la route Dawson se trouve une jolie colline de sable connue sous le nom de "Coteau Pelé." Snow construisit sur ce coteau une maison spacieuse destinée à recevoir et à loger les émigrants. Cette maison, dans la pensee des arpenteurs, devait être le noyau d'une grande ville, à laquelle ils donnèrent à l'avance le nom d'un raffineur de Montréal (Redpath). Au pied de cette colline, dans un angle formé par la rivière des sources se trouvait un cimetière sauvage. La ville de Redpath et le cimetière subirent le même sort, le silence, l'abandon et l'oubli.

En vertu d'instructions transmises au parti des arpenteurs le 10 juillet 1869, par le Ministre des Travaux publics à Ottawa, ils devaient choisir et arpenter plusieurs cantons pour des établissements immédiats dans les meilleurs places et notamment à la Grande Pointe des Chênes, à la rivière LaSalle et sur la Rivière Rouge. Bref on se proposait de tailler des domaines pour les futurs émigrants d'Ontario, sans se soucier des droits acquis sur ces terres pour les anciens colons du pays. Ces derniers devaient être refoulés vers le nord-ouest pour donner place aux nouveaux venus.

Les arpenteurs completèrent la route Dawson en 1869, de manière à la rendre passable ou à peu près. Cette voie a vu passer tour à tour les volontaires d'Ontario, et le colonel Wolseley à son retour à Montréal. Le futur maréchal avait pour guide deux Métis de Sainte-Anne. Plus tard Lord Dufferin suivit également cette route. L'Honorable Charles Nolin lui présenta une adresse à son passage à Sainte Anne. C'est encore par ce chemin que furent transportés des provisions, de la dynamite, de la glycerine et autres matériaux pour les premiers travaux du Pacifique Canadien au Portage du Rat (Kenora). Lorsque M. Giroux vint se fixer permanemment à Sainte Anne, il avait pu suivre, durant ses nombreuses visites, les évènements que je viens de relater et prendre contact depuis deux ans avec la population. Comme ses prédécesseurs, il fut reçu à bras ouverts par le père Morin. Son premier soin fut de construire un presbytère sur le lot 56, auprès du chemin Dawson. Ce presbytère servit également d'école. Ce fut dans se presbytère que Mde. Gauthier et plus tard M. Theophile Paré firent la classe.

Il prit possession de cette modeste demeure le 31 decembre 1870. Pendant 2 ans il y resta seul et allait prendre ses repas à la résidence de Jean-Baptiste Valiquette. Ce dernier avait épousé Delle Ursule Grenier.

La compagnie de la Baie d'Hudson avait fait venir cette jeune fille d'Yamachiche, P.Q., pour apprendre aux femmes du pays à tisser la toile et la laine.

M. and Madame Valiquette étaient heureux d'avoir un prètre à leur portée et lui donnaient la pension gratuitement. La residence permanente de M. Giroux à Sainte-Anne date du 15 septembre 1870. Ce fut une grande joie pour les colons qui depuis plusieurs années imploraient cette faveur de Monseigneur Taché. Ce digne prélat aurait bien désiré se rendre plus tôt à leur désir, mais à son grand regret il n'avait point de prêtre dont il put disposer.

Le presbytère de M. Giroux ne fut construit que tard à l'automne de 1870. Le carré etait de pièces d'épinette rouge, dont les joints étaient enduits en mortier. Les gelées firent retirer les joints; l'enduit même tomba en partie à certains endroits. On peut s'imaginer que durant ce premier hiver, M. Giroux eut beaucoup à souffrir du froid. Ce presbytère ne comprenait que 20 pieds carrés. En 1872 il y fit ajouter une allonge de 10 pieds, qui lui servit de bureau et de chambre à coucher. M. Giroux habita ce presbytère pendant 27 ans. En 1898 lorsqu'il érigea l'église actuelle, il y construisit également un nouveau presbytère, dans lequel il résida jusqu'à sa mort.

La première chapelle élevée sur le lot 19 par le P. Lefloch O.M.I., fut transportée sur le lot 56 par M. Giroux en 1872. Elle était surmontée d'un joli clocher. Une cloche à la voix argentine appelait les fidèles à l'office divin. Cette cloche avait été achetée à Saint-Paul en 1866 et transportée à travers la prairie par Damase Perreault jusqu'à Sainte-Anne. Elle fut bénite en 1867. De 1872 à 1883 cette cloche fut suspendue à une charpente. Lorsque les bonnes soeurs Grises prirent possession du couvent elle fut installée dans le clocher de cette maison, où elle servit à appeler les fidèles au service divin et les élèves à la classe.

Le lot 56 qui est devenu la terre de l'église, avait été occupé tout d'abord par Mde Augustin Nolin. Elle céda ses droits à la mission. Trois frères Nolin vinrent s'établir à la Rivière Rouge savoir: Joseph, Augustin et Louis. Augustin se fixa sur la terre occupée actuellement par la maison provinciale des soeurs de la charité de Saint-Boniface. Il avait pour voisin au nord, Louis Jolicoeur qui transporta ses droits à Monseigneur Provencher et reçut en échange la terre sur laquelle se trouve le parc aux Ormes (Elm Park). La cathédrale et l'archévéché sont construits sur l'ancienne terre de Louis Jolicoeur. Le veuve d'Augustin Nolin alla ensuite demeurer à Sainte-Anne sur le lot 56. Elle avait pour voisin (lot 57) Jean Baptiste Gauthier. La fille de ce dernier fut la première institutrice à Sainte-Anne, sous le gouvernement d'Assiniboia. En 1873, J. Bte. Gauthier vendit sa terre à la mission et alla demeurer à Lorette.

Tout en étant curé de Sainte Anne, M. Giroux n'en continua pas moins jusqu'à sa mort à desservir des missions qui sont devenues depuis des paroisses.

Dès l'été de 1871, il se rendit à la Rivière aux Saules et donna une mission à un parti nombreux de travailleurs employés à des travaux sur la route Dawson.

En 1872, il fit transporter la chapelle du P. Lefloch sur la terre de la mission. De 1871 à 1872 M. Giroux disait la messe sur semaine dans son presbytère et le dimanche dans la chapelle sur la terre de J. Bte. Perreault. La même année (1872) Monseigneur Taché fit sa visite pastorale à Sainte-Anne des Chênes. M. Joseph Nolin lui présenta au nom de la population une adresse dans laquelle il remerciait Sa Grandeur de son dévouement pour la défense des droits de la nation métisse.

Monseigneur fut très sensible à cette expression de sentiments qui rendait si bien la tendre affection qu'il portait aux anciens du pays. Il félicita leur pasteur des progrès opérés dans la paroisse par le zèle l'initiative et les sacrifices de M. Giroux. Cette visite fut une grande consolation pour le pasteur et les fidèles. Jusqu'en 1873 M. Giroux allait dire la messe à Lorette dans une maison privée, car il n'y avait pas de chapelle. Le 1er novembre de cette année (1873) M. J. D. Fillion le remplaca à Lorette et depuis lors un prètre de l'archévéché visita régulièrement cette mission tous les quinze jours.

Nous l'avons deja dit, M. Giroux était d'une grande prudence; ou pourrait peut être ajouter qu'au premier abord, il était sans défense coutre la dissimulation. Lorsqu'il s'apercevait d'une malice que ses amis intimes avaient voulu lui faire, il était le premier à en rire. C'est ainsi qu'un jour il revenait un dimanche matin de Lorette où M. Jean Baptiste Desautels était allé le chercher pour chanter la grande messe à Sainte Anne. Et voila qu'à une couple de milles de la chapelle de Sainte-Anne, M. Desautels se mit à fouetter violemment ses chevaux. Mais, lui dit M. Giroux, pourquoi lancez-vous ainsi vos chevaux? C'est que lui repondit Desautels, je crains d'arriver trop tard pour la messe—"Mais, repliqua M. Giroux, il n'y a pas de danger puisque je suis ici"—A peine avait il prononcé ces mots que voyant M. Desautels s'éclater de rire, M. Giroux lui dit: "Ah méchant que vous êtes, vous m'avez tendu un piège et je suis tombé dedans." Déchargé de Lorette, il porta ses soins sur les nouveaux colons de Saint-Joachim de La Broquerie. On peut dire, en toute vérité que La Broquerie, Thibaultville et Sainte-Geneviève sout des filles de la paroisse de Sainte-Anne et ont eu pour premier père commun le premier curé de Sainte-Anne.

En rendant ainsi hommage à l'esprit apostolique de M. Giroux, je sais que je n'enlève rien des mérites éminents des premiers prêtres résidents de ces paroisses, qui ont rendu si féconde la première semence jetée en terre par leur devancier. Ce n'est qu'en 1884 que M. Guay vint demeurer à St.-Joachim de La Broquerie et déchargea M. Giroux de la desserte de cette paroisse, Monseigneur Taché fit sa visite pastorale à Saint-Joachim pour la première fois en 1886. M. Giroux depuis le 15 septembre 1870 fut de facto curé de la paroisse de Sainte-Anne. L'était il *de jure*? Serait il plus exact de dire qu'il était desservant de la mission de Sainte-Anne? Je n'insiste pas sur ce point. Ce qu'il y a de certain c'est que le 11 avril 1876 Monseigneur Taché erigea canoniquement Sainte-Anne en paroisse et en nomma M. Giroux curé.

L'érection canonique de Sainte-Anne termine ce chapitre. Pour ne pas trop s'éloigner de Sainte-Anne, théatre ordinaire des travaux de M. Giroux, j'ai du sacrifier l'ordre chronologique et réserver à la fin de ce chapitre les quatre missions qu'il donna au Fort Francis en 1873, 1874, 1875 et 1876. La distance aller et retour était près de 500 milles.

Le trajet se faisait en voiture à travers la foret, en suivant la route Dawson, jusqu'au fort de la compagnie de la Baie d'Hudson, à l'angle du nord-ouest. De ce poste les voyageurs prenaient les canots, traversaient le lac des Bois et remontaient la Rivière La Pluie jusqu'au Fort Francis.

M. Giroux fit ce long et pénible voyage pendant quatre années consécutives. Nous avous la bonne fortune de posséder le réçit de sa première mission en 1873, qui a été reproduit dans les Cloches (vol. 1, p. 397-423).

Il serait fastidieux de suivre par ordre chronologique les événements ordinaires de la vie de M. Giroux.

Il suffira de noter les plus importants et de donner une idée d'ensemble.

En 1878 M. Giroux fit ériger une église pour remplacer la chapelle du P. Lefloch. Elle servit au culte jusqu'au 1er novembre 1898, date à laquelle le sanctuaire actuel a été béni par Monseigneur Langevin.

Ce deuxième temple avait environ 70 pieds de long et 25 de largeur. Comme la première chapelle il avait été construit en boulins d'épinette rouge équarris. Il ne fut jamais terminé. Pendant les grands froids d'hiver, il était loin d'être chaud. La pauvre cloche qui conviait les fidèles aux offices pesait 130 livres. Cette cloche, la première qui se fit entendre des fidèles, lance encore ses sons harmoineux dans le clocher du couvent de Sainte-Anne. C'est en 1883 quelle fut transportée au couvent. Le 11 août 1915, trois nouvelles cloches fabriquées par la maison Paccard, Annecy le vieux, France, et achetées par Monsieur le Curé Jubinville, successeur de M. Giroux, furent bénites par Monseigneur Béliveau et finent entendre leurs voix mélodieuses, à cette occasion.

M. Giroux avait une dévotion ardente envers la bonne sainte Anne. Il se fit l'apôtre de cette dévotion et s'efforça de la répandre dans toute la province. Dès 1878 ou voit des groupes de fidèles venir en nombre des paroisses avoisinantes, pour solliciter des faveurs particulières de cette grande Thaumaturge. Il faut bien avouer cependant que l'église était peu attrayante. Elle était d'un tel dénument qu'il fallait une foi vive pour exciter les pélérins à la visiter. On entendait parfois répéter: "Mais comment voulez-vous que sainte Anne fasse des miracles dans un si pauvre temple." La bonne sainte Anne n'était pas cependant de cette opinion car elle récompensa la piété des fidèles par des miracles bien authentiques. A tous les ans le nombre des pélérins accusait un progrès sensible; c'est ainsi qu'en 1888, plus de 700 personnes s'approchèrent de la Sainte-Table. Monseigneur Taché avait voulu lui même présider à ce pélérinage.

Jusqu'au printemps de 1899 le trajet se faisait en voiture. Cette année là, la compagnie du Pacifique Canadien du nord commença transporter les voyageurs entre Winnipeg et le fort William vià le Fort Francis. Il n'y avait que quelques mois que l'église actuelle avait été ouverte au culte. Dès lors les fidèles affluèrent de toutes parts au nouveau sanctuaire—jusque même des Etats-Unis.

M. Giroux eut la grande consolation de voir Monseigneur Langevin et, après lui, Monseigneur Beliveau suivant l'exemple de Monseigneur Taché, se mettre à la tête des pélérinages et entrainer les foules au sanctuaire de la bonne sainte Anne.

Le 3 juiller 1899, Monseigneur Langevin, dans son rapport sur la visite pastorate de cette paroisse avait écrit ces lignes prophétiques: "Nous avous l'espoir que Sainte-Anne des Chênes sera un lieu de pélérinage béni pour tout le diocèse."

M. Giroux eut la douce consolation de voir ces souhaits se réaliser.

Depuis 1889 ou peut dire que des milliers de fidèles vont vénérer les reliques de la bonne sainte Anne et communient au mois de juillet dans le nouveau sanctuaire. L'élan est donné, pour ne plus se ralentir. Des guérisons nombreuses ont lieu presqu'à tous les ans. D'ordinaire la foule s'organise à la garc et se rend en procession, drapeaux en tête, en chantant des cantiques en l'honneur de sainte Anne. Au départ, s'élève de toutes les poitrines ce cri d'amour et de confiance "Vive la bonne Sainte-Anne." Ces manifestations religieuses attestent de la foi robuste de notre population et sont une source de benédiction pour les catholiques de notre province.

En 1901 M. Giroux, constatant qu'un nombre assez considérable de colons s'était fixé sur le chemin Dawson à une dizaine de milles du village de Sainte-Anne, alla les visiter dans le but d'y établir une mission. Le 1^er^ août 1901 il y dit la première messe dans la maison d'école. Il donna à cette mission le nom de "L'enfant Jésus de Thibaultville." Le 22 août de la même année il planta une croix sur la propriété d'Alfred Neault qui appartenait autrefois à Julien Huppé. Il y chanta la première grande messe dans la maison d'école le 1^er^ mars 1903.

M. Giroux dès 1903, commença à sentir les atteintes d'une maladie qui devait le conduire au tombeau. D'ailleurs le couvent et la paroisse ne lui laissaient guère de temps à consacrer à cette nouvelle mission. Il demanda un vicaire. A cette époque, c'était presqu'un luxe pour un curé que d'avoir un assistant. Monseigneur Langevin lui envoga M. l'abbé Alexandre Defoy, avec l'entente qu'il prendrait bientôt charge de Thibaultville. Il demeura vicaire du 20 fevrier 1903 au 26 mars 1904 date à laquelle il fut promu à la cure de Thibaultville. Le 31 juillet 1905 M. le curé Giroux bénit la cloche de Thibaultville qu'il avait été le premier à desservir.

D'où vient ce nom de Thibaultville? M. Jean Baptiste Thibault fut envoyé en 1842 par Monseigneur Taché jusqu'au fort des Prairies (Edmonton). Il fut le premier missionnaire qui se rendit jusqu'aux pieds des Montagnes Rocheuses. Après l'incendie de la cathédrale de Monseigneur Provencher, son successeur Monseigneur Taché descendit dans la Province de Québec pour y recueillir des aumônes et commença les travaux d'une nouvelle cathédrale. M. Thibault fut chargé de faire préparer le bois destiné au nouvel édifice. Il se rendit avec des ouvriers au "Coteau Pelé" près du chemin Dawson et y installa un échafaud pour scier à bras la planche et les madriers nécessaires à la nouvelle construction. On donna à tort ou à raison à cet echafaud le nom de "Hourd." Au moyen âge ou appelait "Hourd" une tour que l'on dressait pour les spectacles de tournois. Le seul tournoi au "Coteau Pelé" était entre les scieurs, à qui préparerait le plus grand nombre de planches d'épinette rouge en moins de temps.

Pour honorer la mémoire de ce vétéran des missionnaires et en souvenir des travaux de M. Thibault au "Coteau Pelé" la nouvelle mission reçut le nom de Thibaultville.

A peine avait il cessé de desservir Thibaultville, que M. Giroux ouvrit une autre mission à Sainte-Geneviéve.

Dès 1904 il visita regulièrement ce dernier endroit. Son vicaire M. Nadeau le remplaçait à diverses époques. Le missionnaire disait la messe dans la maison de Louis Saltel ou Wm. Desrosiers.

En 1906, la mission comptait 75 catholiques mais l'année suivante la population s'élevait à 93 dont 53 communiants.

Monseigneur Langevin en donnant le nom de la paroisse natale de M. Giroux (Sainte-Geneviève) voulait honorer le zèle de ce dévoué curé. En 1908 M. Giroux se rendit à Sainte-Geneviève et donna à la paroisse une chapelle complète. Tous ces objets du culte avaient été conservés dans une cassette, il y avait 40 ans, et avaient servi aux missions du Fort Francis, Lorette, La Broquerie et Thibaultville. Il demeura chargé de cette mission jusqu'à sa mort. A tous les samedis, son vicaire ou lui-même partaient pour Sainte-Geneviève, y faisait l'office le dimanche et revenait le lundi suivant.

IV

Depuis plusieurs années M. Giroux sentait le besoin de construire une nouvelle église plus somptueuse et plus convenable que celle qu'il avait érigée en 1878. Les développements de sa paroisse lui permettaient cette entreprise. Il fit appel à la générosité des fidèles et le 26 juillet 1895 Monseigneur Langevin bénissait la pierre angulaire du nouveau temple.

L'année suivante, le 16 juillet, étant l'anniversaire de l'arrivée de Monseigneur Provencher à la Rivière Rouge, il bénit la croix du cimetière. La nouvelle église est en brique. Elle a 152 pieds de longueur y compris la sacristie et 73 pieds de largeur, en y comprenant les transepts. Le chœur est de 27×26. La hauteur de l'église est de 122 pieds, du sol au sommet de la flèche. Elle fut ouverte au culte en 1898.

Le 27 septembre 1903 fut un jour de grande joie pour le pasteur et les fidèles de Sainte-Anne, M. L. G. Bélanger enfant de la paroisse était ordonné prêtre à Sainte-Anne. Il est le premier prêtre né au Manitoba. M. Giroux était son parrain et eut la consolation de l'assister à sa première messe le lendemain matin.

La même année, M. Giroux fit dorer un calice qui lui rappelait un bien doux souvenir. Sur son lit de mort, M. François Régis Gagnon, curé de Berthier, avait chargé un prètre de faire parvenir ce ciboire à M. Giroux, comme enfant de sa paroisse. Il le reçut le 15 fevrier 1873. Il ne voulut jamais se départir de ce présent qui lui rappelait le sol natal.

Le 8 décembre 1904, dans le monde entier, les noces d'or de la proclamation du dogme de l'immaculée conception furent célébrées avec pompe, éclat et dévotion. M. Giroux fit coincider cette belle fête en l'honneur de la Sainte-Vierge avec l'inauguration d'un nouvel orgue construit par la maison Casavant de Saint Hyacinthe. C'était le Rev. P. Grenier S.J. qui avait réussi à solliciter dans la Province de Québec les fonds nécessaires pour l'achat de cet instrument. M. Giroux le fit installer et pour la première fois il fit résonner la voûte de la nouvelle église de ses sons harmonieux, à l'occasion de cette fête. Pour couronner le tout, dans la soirée, toutes les résidences du village furent illuminées.

Le récensement de 1904 constatait une population catholique de 1284 ames. L'école du couvent était fréquentée par 150 enfants. Quatre autres écoles étaient ouvertes dans la paroisse, savoir: Caledonia, Raymond, Sainte-Anne Centre et Saint-Anne Ouest.

Le 25 juin 1905 Monseigneur Langevin durant sa visite pastorale, bénit la belle statue de Sainte-Anne, qui orne la façade de l'église. Il y confirma plus de cent enfants, c'est à dire plus du double de ceux qu'avait confirmés Monseigneur Taché en 1886. C'est assez dire que la paroisse s'était merveilleusement développée.

En 1906 M. Giroux éprouvait une grande joie en voyant son vieil ami et paroissien élevé au sacerdoce dans la personne de M. Théophile Paré. Il fut ordonné le 26 juillet 1906 dans l'église de Sainte-Anne par Monseigneur Langevin. M. Paré après avoir été longtemps procureur de l'Archévèché, a du se désister de ses fonctions vu l'état précaire sa santé. Il continue néanmoins à rendre encore de précieux services au bureau de la procure. Né à Lachine P.Q. il arriva à Sainte-Anne en 1872 où il fut successivement instituteur, secrétaire trésorier de la municipalité, notaire public, régistrateur et pendant 8 ans, député à la législature provinciale de Manitoba, pour le comté de Lavérendrye. Il fut toujours le confident intime et l'ami sincère de M. Giroux. Il quitta la paroisse de Sainte-Anne pour aller résider à l'archévèché le 13 juin 1904.

Le 26 juillet 1907 la joie débordait partout dans la paroisse de Sainte-Anne. M. Beliveau, aujourd'hui Monseigneur l'archévèque de Saint-Boniface, avait organisé un couvoi spécial pour les nombreux pélérins qui se rendaient à une nouvelle fête à Sainte-Anne. Ce jour là, Monseigneur Langevin élevait au sacerdoce un autre enfant de la paroisse dans la personne du Rev. P. Josaphat Magnan O.M.I. neveu du digne curé de Sainte-Anne. L'église put à peine contenir la foule qu'attirait ce double évènement d'une ordination et d'un pélérinage. Ce jour là, il semble que M. Giroux pauvait entonner "Et nunc dimittis servum tuum." Ses œuvres étaient à peu près terminées. On remarqua en effet, qu'à certains jours, un nuage de tristesse passait sur son front. De temps à autre il dut prendre le chemin de l'hopital. A ceux qui l'interrogeaient sur l'état de sa santé, il avait l'habitude de répondre: "Je me sens vieux et je sens bien que je ne vivrai pas longtemps. Je me tiens prêt à partir."

Préoccupé de cette pensée, il se mit en 1908 à rédiger des notes sur les commencements de Sainte-Anne et la même année il dépensa presque tout ce qui lui restait d'économies pour compléter l'intérieur de son église.

Dans ses notes, ou trouve les quelques lignes suivantes qui synthétisent sa pensée intime et le but ultime que poursuivaient ses efforts incessants depuis 1870.

"Il faut espérer, dit il, que le sanctuaire de Sainte-Anne des Chênes deviendra pour le nord-ouest ce qu'est Sainte-Anne de Beaupré pour la province de Québec, un sanctuaire où les catholiques viendront retremper leur foi et leur esprit national."

L'esprit national, il le prouva bien, en ornant la voûte du drapeau Carillon Sacre-Cœur, enguirlandé de feuilles d'érables. Il était fidèlè à sa race comme il l'était à Dieu. A peine avait il formulé ces vœux qu'il put entrevoir la réalisation de ses espérances. En effet en 1909 et en 1910 plus de mille pélerins visitèrent le sanctuaire de Sainte-Anne. L'église ne pouvant contenir tous les fidèles on dut organiser plusieurs pèlérinages durant ces deux années. Après avoir semé dans le sacrifice et de longs labeurs, il commerçait à récolter dans la joie.

En 1910, il fit poser dans son église de nouveaux bancs. Ce furent les derniers travaux importants qu'il entreprit. Dieu content de son serviteur allait bientôt l'appeler à lui pour lui donner la récompense qu'il avait si bien méritée.

La mort de M. Giroux fut foudroyante. Il avait prévu et annoncé que le coup fatal le terrasserait subitement. Il sentait deja les attaques de l'apoplexie qui l'avertissaient de sa fin prochaine. Il était prêt à subir l'arrêt fatal qui pèse sur notre pauvre humanité. Le 10 novembre il visita les malades de la paroisse comme d'habitude. Le 11 novembre 1911, il se leva comme d'habitude à 5 heures et se préparait à se mettre en oraison lorsqu'il sentit qu'il faiblissait.

Il appela aussitôt à son secours M. l'abbé Leo Rivard son vicaire. Ce dernier accourut et le trouva affaissé dans sa chaise. Il lui donna aussitôt l'absolution et les derniers sacrements. Il essaya de lui procurer quelque soulagement et fit mander les Sœurs du couvent. Ces dernières purent assister à ses derniers moments. Il expira à 5 heures 45 minutes.

La population de Sainte-Anne, témoin des 43 années de son dévouement de sa vie sacerdotale, de sa charité pour les pauvres, de sa sollicitude toujours en éveil pour répandre les bienfaits de l'éducation chrétienne, fut émue jusqu'aux larmes lorsqu'elle apprit la mort de son pasteur et de son père.

Les funérailles eurent lieu le 14 novembre. Mgr. Langevin, accompagné d'une trentaine de prêtres, présida aux obsèques et prononça l'éloge du défunt. Ce serait déflorer cette pièce d'éloquence que d'en présenter une analyse. Le texte entier en a été publié dans les "Cloches" du 15 décembre 1911 (vol. X, p. 421). Rien ne résume mieux la vie de dévouement de M. Giroux que le texte choisi à cette occasion par Mgr. l'archevêque de Saint-Boniface: "*Bonus pastor animam suam dat pro ovibus suis.*"

La Vie des Chantiers

Par E.-Z. MASSICOTTE, M.S.R.C.

(Lu à la réunion de mai 1922)

L'exploitation systématique de nos forêts ne date que d'une centaine d'années. Qui le croirait si l'assertion n'en était faite avec preuve à l'appui, par feu le sénateur Tassé, dans l'instructive étude qu'il consacra naguère à cet admirable colon, le fondateur de la ville de Hull.[1]?

Sous le régime français, il se fit des tentatives de monopolisation de nos meilleurs bois au profit de la marine royale, mais il n'en résulta rien de pratique. La traite des fourrures exerçait sa fascination sur la plupart des gens d'affaires et les empêchait de songer à d'autres sortes de trafic. Les Anglais ne firent pas mieux au dix-huitième siècle.

Il fallut attendre l'arrivée de l'américan Wright parmi nous pour voir naître l'industrie forestière, de même que Montréal avait attendu la venue d'un autre américain, Franklin, pour obtenir une imprimerie.

C'est au mois de février 1800 que Philémon Wright quitta le Massachusetts pour venir s'établir aux confins ouest de la province de Québec. En 1806, il lançait, à travers les rapides de l'Ottawa, le premier train de bois qui "ait jamais flotté sur cette rivière" et il se rendait à Montréal après trente-cinq jours d'un voyage fort pénible, mais plein d'expérience profitable, puisque la deuxième "cage" parvint à destination en 24 heures.

Le grand commerce de bois industriel était créé et devait croître dans des proportions extraordinaires. En 1846, cette industrie employait déjà 7,200 bûcherons; en 1887, près de 40,000 hommes travaillaient dans les "chantiers."

Le mot voyageur

Si l'industrie du bois est à peine centenaire, par contre les "voyageurs" existent depuis les débuts de la colonie, et voici comment. Au temps de la Nouvelle-France tous ceux qui allaient trafiquer avec les Sauvages portaient le nom de "voyageurs des pays d'en haut." Plus tard, on accorda ce titre aux canotiers qui manœuvraient les embarcations chargées de marchandises, de vivres et de munitions

[1]Joseph Tassé, *Philémon Wright ou colonisation et commerce de bois.* Montréal, 1871.

destinées aux postes lointains. Après la disparition des traiteurs l'expression "voyageur" s'appliqua aux bûcherons qui partaient chaque automne pour monter "en chantier."

Un témoin du passé

Tout le monde a entendu parler de la vie que mènent les bûcherons dans les chantiers, mais peu de gens en ont une idée exacte, parce que les informations précises et suffisamment copieuses n'ont pas encore été rassemblées. Il peut donc être intéressant d'entendre sur le sujet le récit d'un témoin oculaire et auriculaire.

Pour nous renseigner, nous avons choisi M. Joseph Rousselle né à Saint-Denis, comté de Kamouraska en 1872, et qui, à partir de 1888, "hiverna" pendant onze ans dans les chantiers du Québec et de l'Ontario ainsi que dans ceux du Maine.

A l'été, pour faire un changement, notre homme allait prendre du service sur les goélettes qui naviguent entre la Gaspésie et les îles Saint-Pierre et Miquelon.

Est-il besoin d'ajouter que M. Rousselle est non seulement au courant de la vie dans les chantiers, mais encore qu'il a profité des milieux propices où il s'est trouvé pour apprendre des quantités de chansons, de contes et d'historiettes? Ceux qui ont assisté aux soirées de folklore données à Montréal ont eu l'occasion d'en juger.

L'engagement

Aller "hiverner en chantier," c'est-à-dire travailler pendant cinq à six mois à l'abattage des arbres forestiers, était un rêve que caressaient jadis grand nombre de jeunes gens de la campagne. Les uns voyaient là un moyen de s'émanciper, d'essayer leurs ailes, de voir du pays, plusieurs se sentaient invinciblement attirés par la soif de l'inconnu, du mystérieux et des aventures et n'avaient aucun but précis; d'autres, plus sérieux, plus positifs, ne cherchaient qu'une occasion propice "de faire de l'argent" pour ensuite s'établir et fonder une famille.

Celui qui projetait d'embrasser la carrière de "voyageur" commençait par se *poster* sur les compagnies qui "faisaient chantier" et, son choix arrêté, il se rendait à l'endroit où on racolait les bûcherons.

En 1888, lorsqu'il débuta, M. Joseph Rousselle n'avait que seize ans et il suivait son père qui partait s'engager à Saint-Pacôme, comté de Kamouraska, où les MM. King avaient un moulin à scie.

Les salaires

Les salaires variaient entre $12 et $14 par mois, selon l'habileté et l'expérience des engagés.

Le père de M. Rousselle fit, vers cette époque, un hivernement qu'il considéra comme tout à fait mémorable, car en huit mois et quatre jours, il avait gagné $104. N'est-ce pas que cette somme paraîtra dérisoire aux bûcherons de 1920 qui n'eurent aucune difficulté à obtenir $75, $100 et $125 par mois et qui, en plus, étaient logés et nourris d'une façon dont les anciens n'avaient aucune idée?

Le départ pour la forêt

Les bûcherons engagés se rendaient vers une certaine date à Saint-Pacôme, pour rencontrer M. François Roy dit Desjardins qui était le grand "foreman" des King. Lorsque tous étaient arrivés, M. Roy prenait "les devants" dans une de ces voitures appelées par les uns "planches" et par les autres "barouches" et *buckboard*.

Les engagés suivaient le premier contremaître à pied, leur "paqueton" au dos. Arrivé à la fin de la route carossable, M. Roy réunissait son monde et procédait à la division des *gangs* ou groupes. A chaque sous-contremaître ou *petit foreman* il assignait un nombre d'hommes et lui désignait une localité forestière: Sainte-Perpétue, la rivière Damnée, la rivière Ouelle, etc.

Ceci réglé, tous partaient à travers la forêt. En 1888, M. Rousselle marcha 24 milles pour se rendre au lieu où sa *gang* devait établir ses quartiers.

La garde-robe d'un bûcheron

Ordinairement, le bûcheron emportait, en plus du complet et des sous-vêtements qu'il avait "sur lui" une couple de pantalons et un "quatre-poches" ou *coat* d'étoffe du pays, des chemises, des "corps" et des caleçons de flanelle ou de droguet tissés à la maison, deux paires de mitaines et trois paires de "chaussons" de grosse laine, une paire de "bottes sauvages" appelées aussi "bottes de bœuf" et un couteau à gaîne.

A cet équipement, quelques-uns ajoutaient du tabac, une fourchette, du thé, une tasse et un instrument de musique. Tout cela—sauf les gros instruments de musique—entrait dans une poche que le bûcheron devait porter sur son dos, à la mode des Indiens.

Placée horizontalement sur les deux épaules, la poche était maintenue en position au moyen d'une courroie dont les bouts étaient fixés aux deux extrémités de la poche et dont le centre, large de trois doigts, reposait sur le front du porteur.

Autre détail: Les bûcherons pouvaient acheter de la compagnie King du tabac anglais pressé "en mains" qui se chiquait ou se fumait. Elle le vendait un dollar la livre, ce qui pour l'époque était un fort bon prix.

Enfin, les raquettes, indispensables à tout bûcheron, étaient fournies par la Compagnie.

Le campe

Au centre de la forêt qu'il fallait bûcher on élevait le *campe.*[2] Autant que possible on avait choisi un emplacement sis près d'une rivière ou d'un ruisseau. Le *campe* ou hutte était construit en bois rond: sapin ou épinette. Jamais on n'employait de bois blanc: tremble ou peuplier parce que rien n'est plus malchanceux. Depuis beau temps les voyageurs ont constaté que dans un *campe* en bois blanc il arrivait toujours quelque malheur au cours d'un hivernement.

Les dimensions du *campe* variaient suivant le nombre de personnes qui devaient l'habiter. Ordinairement, il avait 30 par 40 pieds en superficie. Le plancher reposait sur le sol et il était en tronc d'arbres dont on avait "abattu" les nœuds à l'herminette. A huit pieds au-dessus s'étendait le plafond également en bois rond. Sur ce plafond on mettait une épaisseur de six pouces de terre, afin de mieux conserver la chaleur. Pour terminer la hutte, on la couvrait d'un toit légèrement en pente et fait avec des pièces et bois "en auges."

Les ouvertures consistaient en une porte et deux petites fenêtres de 18 pouces en carré; l'une d'elles était près de la porte et l'autre dans le pan au fond de la hutte. Elles fournissaient au *cook* la lumière dont il avait besoin pour préparer les aliments et mettre un peu d'ordre dans le logement. Non loin du *campe* on élevait une écurie pour abriter une douzaine de chevaux. Ces bêtes de trait devaient trainer les billots coupés chaque jour par les bûcherons.

Attenant au chantier, se trouvait un garde-manger de huit pieds carrés où l'on remisait les provisions.

Le foyer ou "cambuse"

En langage de voyageurs le foyer s'appelle la "cambuse." Celle-ci occupe le centre du campe. L'âtre est constituée par des pierres

[2]Dans la région de Kamouraska, *le campe* c'est la hutte en bois où logent les bûcherons, tandis que *la campe* c'est la tente qui abrite les *draveurs* durant le flottage des billots.

plates posées sur le sol et entourées de grosses roches rondes. Comme il n'y a pas de cheminée à la hutte, une ouverture de cinq pieds est pratiquée dans le plafond et dans le toit, pour laisser échapper la fumée, et pour aérer la pièce. Ajoutons que l'absence de cheminée rendait le campe peu habitable lorsque le temps était "mort" et que la fumée séjournait à l'intérieur du "chantier."

Les lits

Sur les pans de gauche et de droite de la hutte on fixait des lits étagés. Le plus souvent, il y en avait trois rangées. La première était à quelques pouces du plancher; les deux autces la superposaient de deux pieds en deux pieds. Deux hommes couchaient dans chaque lit. Le fond des couchettes était en petits troncs de sapin séparés en deux. Sur ce fond, les bûcherons disposaient une épaisseur de quatre à six pouces de fines branches de sapin blanc. Ceux qui aimaient leurs aises renouvelaient leurs rustiques matelas presque chaque mois, mais les paresseux *toffaient* plus longtemps.

Mobilier de chantier

Dans le *campe* on ne voyait ni table, ni chaise, ni lavabo. Il n'y avait que quelques grands bancs fabriqués de troncs d'arbres fendus en deux et fixés sur quatre pieds en rondins de bois franc. Pour manger, plusieurs bûcherons posaient leur plat sur leurs genoux; d'autres plus industrieux se faisaient des "chiennes." Ce nom bizarre est appliqué par les voyageurs à un petit banc ou selle à trois pieds. Le bûcheron pouvait s'asseoir à cheval sur un bout de la "chienne" et mettre son plat devant lui, sur l'espace resté libre.

Le couvert

Rien de plus sommaire. Les repas étaient servis dans des plats de ferblanc. Chaque homme fournissait son couteau. S'il était délicat, il ajoutait une fourchette qu'il avait emportée. va sans dire, et s'il était buveur de thé, il devait également s'être pourvu de cuillère, de tasse et de thé.

Nourriture

Le menu des bûcherons se composait de pain, de soupe aux pois, de lard salé et de fèves. Quand les chemins permettaient de transporter les vivres en traineaux, la Compagnie ajoutait une grosse mélasse noire dénommée sirop. De rares bûcherons emportaient du thé et s'en infusaient, par-ci par-là.

Le pain et les fèves étaient cuits sous la cendre. Après les avoir déposés dans une marmite couverte, le cuisinier plaçait celle-ci dans l'âtre, sur un lit de braise, puis il recouvrait entièrement le vase de cendres chaudes sur lesquelles il allumait un feu afin d'entrenir la chaleur.

Les uns mangeait la mélasse avec du pain, mais le plus grand nombre la mêlait avec les fèves au lard.

Le premier repas se prenait à l'aube et le second au retour des engagés, c'est-à-dire "à la brunante." Le midi on ne s'accordait qu'un goûter dans le bois, sur l'ouvrage ainsi que nous le disons ci-après.

La journée de travail

Elle commençait "au petit jour." Sitôt le déjeuner avalé, les bûcherons prenaient leurs haches et se rendaient à leur poste, parfois à un mille ou deux. Chacun emportait son dîner, car il ne fallait pas songer à retourner au *campe* pour une semblable bagatelle. Ce repas se composait d'un morceau de pain et d'une tranche de lard lequel était parfois gelé si dûr qu'il fallait le soumettre à la chaleur pour "l'attendrir." Ce qui fait qu'on aimait autant s'en passer quand l'estomac n'était pas "trop creux."

Le travail finissait avec la chute du jour et l'on reprenait la route du *campe*. Cette route était facilement reconnaissable parce qu'elle était "plaquée" ou "blaizée." Autrement dit, on avait pratiqué à la hache des entailles dans les troncs d'arbres, de distance en distance, pour se guider.

Le travail se faisait par équipe de deux bûcherons et d'un charretier. Deux hommes étaient supposés bûcher, chaque jour, environ 50 billots de douze pieds. Le chiffre variait selon les espèces de bois et la densité de la forêt. Un cheval attelé sur une traîne et conduit par un charretier "hâlait" à mesure les billots. On les entassait sur divers points d'où ils pouvaient être facilement lancés à la rivière au temps du dégel.

La "banque"

Il arrivait parfois qu'on abattait plus que le minimum requis, alors l'équipe se faisait une "banque." La banque c'est une réserve accumulée aux jours où l'on travaille plus qu'à l'ordinaire et dans laquelle on puise lorsque le mauvais temps rend le travail trop difficile, ou lorsque le beau temps donne au voyageur l'idée de flâner. Dans ce dernier cas, on monte à la tête des pins ou des épinettes et l'on se chauffe au soleil "comme des lézards." Ces instants de paresse, sous les accolades du renouveau ont une douceur qui fait oublier bien des heures pénibles, telles par exemple celles où il avait fallu couper un arbre dont le tronc était engagé dans une épaisse neige folle et molle. Souvent alors on enfonçait jusqu'à la poitrine. Imaginez en quel état le bûcheron arrivait au *campe* après une semblable journée!

Toilette et lessive

Les chantiers d'autrefois n'étaient pas pourvus de lavabos, de serviettes ni de savon, ce qui rendait la toilette générale des plus succintes. Les bûcherons couchaient tout habillés et ne changeaient de sous-vêtements "qu'avec raison." Est-il besoin d'ajouter que dans ces conditions, le vermine qui s'attaque à l'homme ne manquait pas de visiter les *campes*?

Pour s'en débarrasser on faisait de temps à autre bouillir les vêtements et le linge dans un grand chaudron où l'on jetait quelques poignées de gros sel. Cela avait un effet magique sur les parasites qui, prétend-on, résistent à un ébouillantage à l'eau douce.

L'approvisionnement

A l'automne et au printemps, le terre détrempée des routes à peine tracées ne permet pas de voiturer les vivres au chantier. Durant ces périodes, chaque *gang* est obligée de faire transporter ses provisions à dos d'homme. Trois fois la semaine, le contremaître désigne quatre jeunes gens et les envoie chercher les provisions au lieu de ravitaillement général nommé le *dépot campe* sis à quinze ou vingt milles. Les "portageux" s'en vont le matin de bonne heure. Après avoir dîné au dépot, ils repartent chargés chacun d'une poche: l'une contient le lard, l'autre des pois, la troisième des fèves et la dernière de la farine. Il y avait une pesanteur de 64 livres dans chaque poche, qui, comme il a été dit, était placée sur le haut des épaules du porteur et maintenue en place au moyen d'une large courroie passant sur le front.

Les porteurs, de même que les "portageux" chargés de "paquetons", devaient se tenir courbés en avant et faire tout le trajet dans cette position fatigante. S'ils voulaient allumer la pipe ou se reposer un instant ils ne pouvaient que s'appuyer sur un arbre. A l'arrivée au *campe*, les bûcherons s'approchaient au plus tôt des porteurs afin de les débarrasser de leurs sacs, et aussi pour les soutenir et leur aider à s'asseoir ou à se coucher. Cette précaution était nécessaire envers les débutants surtout. Car, après une marche de 15 à 20 milles, ployés sous leurs fardeaux, les novices, dès que leurs épaules étaient allégées du poids qu'elles avaient soutenu durant une demi journée, étaient pris de vertige ou bien ils perdaient l'équilibre et "plongeaient en avant."

L'informateur avait seize ans lorsqu'il fit son premier trajet. Revenu au chantier, il était fatigué au point qu'il rendait l'âme. Il se coucha sans pouvoir souper.

Ce mode d'approvisionnement durait cinq à six semaines, au début et à la fin de l'hivernement; il cessait dès qu'il était possible d'établir des chemins et d'assurer la circulation des traineaux ou des voitures.

Le missionnaire

Un prêtre visite les chantiers dans le cours de l'hiver. C'est un missionnaire spécialement désigné pour cela ou c'est un curé d'une paroisse des alentours. La visite commence par une causerie générale, puis le prêtre sermonne l'auditoire, enfin tout le monde se confesse derrière un écran formé d'une couverte fixée dans un angle de la hutte. Le lendemain matin le messe est dite et la communion est distribuée. A l'issue de la cérémonie, chaque bûcheron offre une petite aumône au missionnaire.

Les veillées du campe

Le soir, après un souper chaud, on tirait une "touche" autour du feu qui flambait dans le foyer. La journée avait été rude et comme il fallait se lever tôt, la causerie durrait peu. Par ailleurs, personne ne devait allumer de chandelle ou de lampe. Seul, le *cook* avait le privilège de faire usage d'un mode d'éclairage quelconque pour vaquer à sa besogne. Tout le monde devait être au lit à 9 heures. Telle était la règle, du dimanche au vendredi soir.

Le samedi soir

Le samedi soir, par exception, on pouvait se coucher tard. C'était la veillée de détente et de réjouissance. On la passait à chanter, à conter des contes, des histoires de revenants, de loups-garous, de feux-follets, de lutins. Chaque chantier formait un foyer de dissémination folklorique. Après un hivernement, les mieux doués savaient toutes les chansons des uns des autres. La danse était également bien estimée quand il se trouvait quelque bûcheron musicien qui avait emporté son instrument: violon, concertina, harmonica (dit "ruine-babines") ou guimbarde (dit bombarde et trompe). S'il n'y avait pas de musique "on dansait sur la gueule." Tout se passait bien, personne ne se dérangeait, la "boisson" n'étant pas tolérée dans les *campes*.

On pratiquait aussi divers jeux ou trucs de force et d'endurance, tels "le tir au bâton," le "tir à la jambette," le "tir au poignet," le "tir au crochet," etc.

Les fêtes

Aux temps des fêtes, les bûcherons avaient huit jours de congé et ceux qui demeuraient dans un rayon de quelques lieues en profitaient pour aller voir leur famille et changer d'atmosphère. Les autres "se faisaient du plaisir" comme ils pouvaient.

La drave

Avec le retour du printemps, la fonte des neiges et la crue des cours d'eau, il fallait songer au flottage des billots. La coupe des bois étant finie, les bûcherons âgés retournaient dans leurs familles et les jeunes restaient pour convoyer les billots jusqu'au moulin. La *drave* procurait un supplément de $4 à $5 par mois aux flotteurs, car c'était un travail ardu, souvent dangereux. Les flotteurs de Kamouraska n'avaient pas de chaussures spéciales: ils portaient des "bottes sauvages" ordinaires. Ils n'avaient pas de *canthook*, mais un simple levier ou pince en bois franc, long de cinq pieds.

La *drave* durait vingt-cinq à trente jours; les flotteurs suivaient les billots sur la grève et s'il y avait dans le cours de la rivière des rapides ou des chutes, ils devaient veiller à empêcher les billes de se *jammer*.

La jamme

Lorsque, malgré tout, une *jamme* se produisait, les bûcherons trouvaient la cause de l'embarras, puis le plus brave se chargeait de rétablir la circulation en déplaçant le billot qui retenait les autres. Le coup de gaffe ou de pince donné, l'audacieux voyageur "volait" sur le rivage, car aussitôt la montagne de bois s'engouffrait avec un bruit d'enfer dans la cataracte furieuse.

Cette opération offrait de tels risques que plusieurs voyageurs perdirent la vie en essayant de libérer un amas formé à la tête d'une chute.

La *drave* terminée, chacun reprenait sa poche et sa paie. On se mouillait le gosier, sec depuis des mois, et l'on partait voir sa "blonde." Toutes les misères étaient oubliées. On se croyait riche et heureux, et comme le bonheur n'est qu'une charmante illusion, ces rudes travailleurs goûtaient quelques jours d'agrément. Ensuite, quand la réalité ou la satiété avait chassé les beaux rêves, on reprenait le collier.

Les chansons de voyageurs

Après avoir été les coryphées du trafic des pelleteries, puis les aides du voiturage par eau, les voyageurs sont devenus, avec le dix-neuvième siècle, les principaux facteurs de l'industrie forestière. Durant chacune de ces phases ils ont fourni à notre patrimoine de traditions, des groupes de chansons qu'on ne peut ignorer.

Aux couplets de leurs prédécesseurs les voyageurs modernes ont parfois greffé des refrains nouveaux, caractéristiques, ou bien, ils ont modifié les anciens textes considérablement afin de leur donner plus de couleur locale. Souvent aussi, ils ont créé des pièces. Celles-ci, faut-il le dire, sont beaucoup plus rudes et frustes que les autres qui nous venaient de France; néanmoins, elles sont précieuses pour quiconque voudra étudier la mentalité de ce groupe de la population.

Le répertoire qui célèbre la vie des voyageurs de chantier est considérable, et pour rester dans les limites que nous nous sommes tracées nous avons éliminé toutes les chansons qui ne concernent nommément que les navigateurs et les voyageurs d'antan. Sauf en un cas ou deux, nous avons même sacrifié—pour l'instant—les pièces démarquées, c'est-à-dire les chansons de canotiers ou de traitants que les bûcherons ont fait leurs en en modifiant quelques termes. Enfin, pour aider à se débrouiller, nous avons divisé notre moisson en cinq catégories et de chacune d'elle nous reproduisons ci-après quelques exemples qui suffiront pour donner une idée du reste.

Chansons de départ et d'engagement

Dans ce groupe la plus typique a été obtenue du colosse des chantiers, Vincent-Ferrier de Repentigny et elle est encore inédite comme toutes celles que nons insérons dans cet article.[3]

I

Arrivant à Lachine,
Là c'est un beau canton.
On s'embarque en *steamboat-e*
Pour monter Carillon.
Arrivé à cett' passe
Faut changer de vaisseau.
On embarque en *railroad-e*
Pour monter le Long-Sault.

[3]Ajoutons immédiatement que toutes les chansons citées ont été légèrement modifiées afin de rétablir la mesure et le sens autant que possible. Chacun peut toutefois consulter les textes exacts que nous avons recueillis, car notre collecton (paroles et airs) est déposée dans les archives de la voix humaine, section d'anthropologie, Ministère des mines, Ottawa.

II

Arrivant à Bytown-*e*
A fallu débarquer.
On entre dans la ville
Pour se faire pensionner.
On a bien 'té trois jour-es
A boire et à manger,
A danser tous les soir-es
Pour se désennuyer.

III

Le lundi faut partir-e
Pour aller s'engager
Chez les messieurs Gilmore
Qui font de grands chantiers.
J'aurai dans la mémoire
Mes parents, mes amis,
Aussi ma très chèr' blonde
Sujet de mes ennuis.

IV

Le mardi faut partir-e
Pour monter en chantier,
Dans la bou' dans la neige,
Notre butin tout g'lé.
On f'ra la réjouissance
Quand tout sera fini,
Qu'on laissera la *drave*
Pour r'tourner au pays.[4]

M. Ernest Gagnon, dans ses *Chansons populaires du Canada*. edition de 1865, p. 163, cite une autre pièce de cette même catégorie.

Chansons d'avirons

Très nombreuses sont les chansons d'avirons et de marche, et c'est dans ce groupe que se trouvent généralement les airs les plus estimés, c'est-à-dire les plus populaires. Un de ces morceaux est bien caractéristique. Il nous vient encore de M. de Repentigny.

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[4]Chantée par V.-F. de Repentigny. Apprise vers 1878. Texte et air dans collection Massicotte.

1

Derrièr' chez nous y'a t'un étang,
Je monte en haut et je descends.
Trois beaux canards s'en vont baignant.

REFRAIN: Je joue du piq', je m'en vas *draver*
Ah! je commence à voyager,
Je monte en haut su' l' bois carré.

2

Trois beaux canards s'en vont baignant, Etc.[5]

Chansons des misères et des accidents du métier

La principale pièce de cette catégorie "Un voyageur qui s'détermine" a été calquée sur une chanson qui décrivait antérieurement les dangers du métier de traiteurs. La pièce moderne comme l'ancienne sont des productions littéraires qui ont dû avoir pour auteur un de ces missionnaires qui visitaient les chantiers ou les postes.

1

Un voyageur qui s'détermine
A s'éloigner pour voyager
Dieu du ciel, il se destine
A braver les plus grands dangers.
Vierge Marie, ô tendre Mère,
Soyez son guide et son soutien,
Secourez-le dans ses misères
Conduisez-le dans son chemin.

2

Il quitte sa pauvre famille
Il embrasse ses vieux parents.
Dans ses yeux une larme brille:
Adieu! je pars, c'est pour longtemps.
Tant de peines et de fatigues
Dans ces forêts bien éloignées,
Dans ces forêts, là, au lointain,
Dans ces bois où l'on fait chantier.

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[5]Chantée par le même. Apprise vers 1880. Texte et air dans la collection Massicotte.

3

Armé d'une pesante hache
Il donn' des coups bien vigoureux.
Il bûche, il frappe sans relâche
L'écho en résonne en tous lieux.
A quels dangers qu'il-e s'expose:
L'arbre le menace en tombant.
Il faut donc penser à la mort
Ainsi qu'à nos bien chers parents.

4

Une grossière nourriture
Un pauvre chantier pour abri.
Parlons de tout ce qu'il endure:
Les poux veule lui ravir la vie.
Dessus la *drave* il va descendre,
Marcher dans l'eau, ramer bien fort,
Aussi va falloir entreprendre
Braver les flots aussi la mort.

5

Pauvr' voyageur que vas-tu faire
Après avoir eu ton paiement?
Vas-tu dans ces infâmes villes?
Là, tu perdras âme et argent.
Au lieu d'aller à la cantine
Va-t'en tout droit chez le banquier,
Evite ce qui cause ta ruine
Tu en seras récompensé.[6]

Voici une pièce très répandue qui nous renseigne sur un accident qui serait arrivé à un nommé Hyacinthe Brisebois. Nous en avons quatre versions venant de différentes parties de la province.

1

Jeunes de campagne
Ecoutez la chanson.
Une chanson nouvelle
Dernièr'ment composée
Un soir, dans un chantier
Etant bien estropié.

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[6]Versions par MM. Joseph Rousselle, V.-F. de Repentigny, Georges Monarque et Roméo Jetté. Textes et airs dans collection Massicotte.

2

C'est par un vendredi
J'ai bien manqué mourir,
J'ai bien manqué mourir,
Avant qu'il fut minuit,
Sans aucun sacrement,
Voilà bientôt deux ans.

3

Mes compagnons d'voyage,
Un prêtre ont 'té cherché,
Un prêtre ont 'té cherché,
Pour me réconcilier
Avecque le bon Dieu
Que j'avais délaissé.

4

Le prêtr' m'a conseillé
De laisser le chantier
Sitôt que je pourrai.
Ce n'est qu'au mois d'avril
Que j'ai pu m'embarquer
Avec mes associés.

5

Si jamais je retourne
Au pays d'où je viens,
Je promets au bon Dieu,
A la très Sainte Vierge,
Grand' mess' sera chantée
L'jour de mon arrivée.

6

Grand'mess' sera chantée
Pour tous ces voyageurs
Qui sont dans la misère
L'automne aussi l'hiver,
Le printemps et l'été,
Tout le long de l'année.

7

Qu'en a fait la chanson
Je vais vous dir' son nom.
C'est Hyacinthe Bris'bois
Si vous le connaissez.
L'a faite et composée
Pour se désennuyer.[7]

Mais le bûcheron n'avait pas qu'à compter avec les accidents du métier, il était souvent victime de patrons mesquins et filous. Lisez:

1

M'sieu Dickson c't'un bon garçon (bis)
Un jour, revenant des prisons (bis)
Il n'avait pas grand argent,
Il monta au Fils-du-Grand[8]
C'était pour y fair' chantier
N'croyant pas de nous payer.

2

Quand le *bosse* monte en haut (bis)
Un' façon rien de plus beau (bis)
Le *for'man* lui d'mand' des haches,
Il lui a fait la grimace,
Lui d'mande aussi du sirop,
Lui a fait des yeux d'taureau.

3

Le *cook* a voulu parler (bis)
A propos de notr' manger (bis)
Il lui dit: "Mon petit noir,
Mêle-toi de tes affaires,
Je t'y casserai la face.
Des *cooks* j'en ai bien dompté."

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[7]Versions par MM. Joseph Rousselle, Charles Marleau et Théophile Bronsard. Textes et airs dans collection Massicotte.

[8]Localité sur la rivière du Moine, dit le chanteur.

4

Quand ça vint sur le printemps (bis)
Il nous fit des billets blancs (bis)
Billets blancs, barbouillés d'noir
Pour payer dans l'autre hiver.
Il peut s' les fourrer . . .[9]
Pour moi, j'n'y reviendrai plus.[10]

Chansons de "blondes"

Mais le voyageur ne pouvait se borner à ne chanter que ses misères; c'était souvent un amoureux qui avait laissé une "blonde," là-bas ou qui avait eu quelques aventures romanesques et il imaginait des chants comme ceux qui vont suivre:

1

D'un voyageur je suis aimée (bis)
Il m'a donné tout son cœur
Aussi de bien *belles* gages.
Cela n'me ramène pas
Celui que mon cœur demande.

2

Dans les chantiers s'en est allé (bis)
Le bonheur qu'il m'a laissé:
Ah! bien plus souvent je pleure.
S'il ne revient pas bientôt,
Il faudra bien que je meure.

3

V'là l'printemps qui va t'arriver (bis)
J'entends l'rossignol chanter.
Tous les voyageurs descendent.
Cela me ramènera
Celui que mon cœur demande.[11]

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[9]Nous supprimons ici une expression trop énergique.

[10]Chantée par L.-H. Cantin. Apprise à Hawkesbury, Ont., vers 1886. Texte et air dans collection Massicotte.

[11]Chantée par Ephrem Dessureau. Apprise vers 1865. Texte et air dans collection Massicotte.

Celle-ci est d'un tout autre genre:

1

Par un automn' j'm'suis engagé
Dans un chantier pour hiverner.
J'avais pas fait trois, quatr' voyages
J'me suis t'amouraché d'un' fille.

Refrain: Sur le *right fall* a *day*
Right fall a tour
Right tour *all day.*

2

A mon *for'man* j'm'suis écrié:
(A qui j'contais tous mes secrets)
J'aim' cett' jeun' fill' plus que moi-même,
J's'rais content si c'était la mienne.

3

Ah! tais-toi donc, mon petit fou,
Cett jeun' fill' ne s'ra pas pour vous.
Son amant reviendra de guerre,
Il la mariera, c'est bien clair.

4

J'y ai ach'té des beaux pen' d'oreilles,
Des rubans, aussi des beaux gants.
Ell' les a pris, mais 'n'a eu honte
Vu qu' ça v'nait d'un voyageur.

5

Un lundi, s'est fait un gros bal.
J'ai 'té la chercher pour danser.
Ell' m'a dit: J'aime un autr' que toi,
Mais avec toi, j'irai danser.

6

On a dansé d'la nuit au jour
Et l'matin, j'ai 'té le ram'ner.
Je l'ai m'né, je l'ai t'embrassée . . .
Et elle m'a promis son cœur.[12]

[12]Chantée par L.H. Cantin. Apprise à Kippewa, vers 1898. Texte et air dans collection Massicotte.

Passons à une autre

1

Adieu papa et ma maman
Je vais partir, c'est pour longtemps.
Hélas! que ce départ me coûte,
Quand il faut tous se dire adieu.
Adieu donc, ma charmante blonde,
Adieu donc, tous mes bons amis.

2

Chers amis, je n'vous conseill' pas
D'aller dedans ces pays là.
Tous jeunes gens qui s'engagent
Peuvent dire adieu au plaisir.
Oh! restons donc dans les villages:
Là où on a bien du plaisir.

3

Un' fois partis, fallut monter
Dans les chantiers pour hiverner.
Oh! si vous aviez vu la place,
Comm' c'avait l'air abandonné.
Il fallait être voyageur
Pour consentir à y rester.

4

Petit oiseau, que t'es heureux
De voltiger là où tu veux.
Oh! si j'avais ton avantage
De pouvoir prendre ma volée
Sur les genoux, ah! de ma belle
J'irais souvent m'y reposer.

5

Par un dimanche après-midi
Mon associé m'a demandé:
—Oh! quittons doncque cette place
Afin d'abandonner l'ennui.
Allons vivre dans les villages
Là où c'qu'on aura du plaisir.

6

C'est mon *for'man* qu'j'ai 'té trouvér.
C'était pour me faire payer.
Tous deux nous avons pris la route
Par un lundi de bon matin . . .
Et à la fin de la semaine
Nous avions tous le verre en main.

7

Un soir, allant m'y promener,
Ma bien aimé'j'ai rencontrée.
Elle me salua, sans doute,
Comme toujours d'accoutumée,
Mais son air fier, son air sévère,
M'a dit qu'elle était mariée.

8

—Puisqu'il est vrai qu'vous êt' mariée
Mon anneau d'or donnez-moi lé.
Tu m'avais fait-e la promesse
Ah! que tu m'aimerais toujours.
Puis aujourd'hui tu m'abandonnes
Dedans mes plus tendres amours.

9

—Oui, c'est bien vrai que dans les temps
Où je t'avais pris pour amant
Que tu m'avais dit de t'attendre
L'espace d'un an et demi.
Voilà qu'deux ans s'sont écoulés
Alors, moi je me suis mariée.

10

Qu'est-c'qu'a composé la chanson?
C'est Louis Gagnon, voici son nom.
C'est en descendant sur la *drave*
Avecque tous ses compagnons;
Etant assis sur la lisière
Il nous la chanta tout au long.[13]

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[13]Chantée par Joseph Rousselle. Apprise vers 1893. Texte et air dans collection Massicotte.

Est-il bien nécessaire de rappeler que les bûcherons ne furent pas tous des anges et qu'ils laissèrent souvent traces de leurs moeurs dans les villes où ils se réunissaient en nombre? Une pièce curieuse dont nous n'avons qu'une version nous en fournit l'indice sinon la preuve:

1

C'est dans Bytown qu'ça fait pitié
Tout' les fill' ne font que pleurer
Ell' pleur' leurs cœurs volages
De s'êtr' laissé gagner; bis
Ell' s'sont donné' pour gages
Aux jeun's homm' de chantier.

2

—Quand le chantier-e s'ouvrira
La bell' un' lettr' tu m'écriras.
Tu m'écriras un' lettre
De ta sincérité, bis
Si ton cœur est en peine
Tu m'feras demandé.[14]

Les quatre autres strophes de cette "élégie" populaire sont d'un goût "particulier" et nous préférons les omettre.

Chansons de drave

Nous l'avons déjà dit la *drave* était considérée comme une tâche dangereuse, et les voyageurs appuient sur ce fait dans la plupart de leurs chants. Grande fut la vogue d'une naïve complainte dont nous reproduisons un texte formé de plusieurs versions. Elle nous a été répétée par tous les bûcherons que nous avons connus. Elle doit concerner un tragique accident assez ancien si nous en jugeons par l'âge de nos informateurs:

1

Nous somm' trois frèr' partis pour le voyage.
Dans un chantier nous somm' tous engagés;
Mais le printemps a fallu fair' la *drave*,
Risquer sa vie dans les plus grands dangers.

[14]Chantée par L.-H. Cantin. Apprise à Kippewa, vers 1897. Texte et air dans collection Massicotte.

2

Par un dimanch', dimanche avant-midi,
Dessous un' *jamm'* je me suis englouti.
Je descendais de rapid' en rapides,
Sans une branch' que je puss' rencontrer. .

3

Il faut mourir sous ces eaux qui s'écoulent
Sans un secours, et sans voir le curé.
Vous autr', mes frèr', qui allez voir mon père,
Vous lui direz que je suis décédé.

4

Triste nouvell' pour apprendre à un père
Aussi t'un' mère et à tous mes parents.
Vous leur direz qu'ils ne prenn' point de peine
Car tôt ou tard, il faut subir la mort.[15]

Chansons de retour

La fin de l'hivernement, c'était l'époque du retour dans les régions habitées, dans les familles, vers les parents, les amis, le plaisir. Aussi les chants sont-ils vifs et allègres. On en pourra voir des exemples notables dans *Envoyons d'l'avant nos gens* et *Là ious qu'y sont tous les raftmans* deux pièces que nous avons publiées dans les *Veillées du bon vieux temps.*[16]

Un dernier mot

Nos chansons d'hier et d'autrefois menacent de disparaître parce que nos coutumes se transforment rapidement. Il suffit de noter que les chemins de fer, les automobiles, la chaloupe à essence et les bateaux ont porté un coup mortel à la chanson de marche et d'aviron; que les cinématographes et autres spectacles enlèvent aux gens le goût de se réunir à leurs maisons pour s'amuser; que les gramophones les dispensent de chanter et de jouer d'un instrument pour apercevoir que sous ce rapport une évolution profonde s'accomplit. Avant longtemps, les collections des folkloristes seules pourront renseigner sur bien des côtés de la vie sociale de nos pères.

Devons-nous encourager ces collectionneurs,—thésauriseurs, peut-être?—ou vaut-il mieux les dissuader de poursuivre leur oeuvre?

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[15]Versions par MM. L.-H. Cantin, Philéas Bédard, V.-F. de Repentigny et Philippe Normandin. Textes et airs dans collection Massicotte.

Une autre curieuse chanson de *drave*: *Adieu charmante rive*, a paru dans l'ouvrage de MM. Massicotte et Barbeau, *Chants populaires du Canada* édité par le *Journal of American Folk-lore*, en 1919.

[16]*Veillées du bon vieux temps* à la Bibliothèque Saint-Sulpice, à Montréal les 18 mars et 24 avril 1919. G. Ducharme Montréal 1920.

Au Berceau de Notre Histoire

Par l'abbé H.-A. SCOTT, M.S.R.C.

(Lu à la réunion de mai 1922)

I

Nous plaçons modestement le berceau de notre histoire au temps de Jacques Cartier. Ce n'est pas qu'il n'y ait auparavant rien qui nous touche ou qui puisse nous intéresser. Il suffit, pour voir le contraire, d'un coup d'oeil sur l'important rapport intitulé: *The Precursors of Jacques Cartier*, publié en 1911 par M. H.-P. Biggar, des archives fédérales. On peut y lire nombre de documents italiens, espagnols, portugais, français, anglais, où il est question de notre terre d'Amérique, de monarques qui ont jeté un regard de convoitise, de hardis navigateurs qui ont tendu leur voile vers nos lointains rivages.

Mais comme ces notes n'ont aucune visée à l'érudition, nous laissons volontairement dans l'ombre Henri VII et les Cabots, François I et Verrazano, le roi Emmanuel et les Corte Real. De même, bien que trois quarts de siècle séparent Cartier de Champlain et qu'ils aient fourni au très méritant Dr. N.-E. Dionne la matière d'un volume intéressant, nous passons de notre premier découvreur au Père de la Nouvelle-France, sans rien dire ni du marquis de la Roche, ni de la *France Antarctique* d'André Thévet, ni des *Voyages Avantureux* du Capitaine Jean Alfonce, dont Lescarbot écrit fort irrévérencieusement: "Et peut-il bien appeler ses voyages *avantureux*, non pour lui, qui ne fut jamais en la centième partie des lieux qu'il décrit . . . mais pour ceux qui voudront suivre les routes qu'il ordonne de suivre aux mariniers."[1]

Cartier et Champlain, voilà les deux grandes figures qui dominent toutes les autres au commencement de l'histoire du Canada. Tous nos historiens anciens et modernes leur ont donné le relief qui leur est dû. Mais ceux qui écrivent l'histoire générale sont contraints de ne s'arrêter qu'aux sommets des choses, et, faute d'espace, de négliger les détails. Or, en histoire, c'est le détail qui est intéressant, caractéristique, instructif, et c'est le détail qui se grave dans la mémoire. Il est incontestable que la simple lecture d'un récit circonstancié laissera dans l'esprit plus de traces, des connaissances plus précises, qu'une étude des mêmes faits sommairement racontés. Ainsi, quoique

[1] *Hist. de la No.-France.* Ed. Tross. II, p. 476.

cela puisse paraitre paradoxal, ce n'est pas seulement acquérir une science plus étendue, plus complète, que de préférer les longues histoires aux récits abrégés, même les meilleurs, c'est encore sauver du temps!

Pour l'époque reculée dont il est ici question, nous avons la bonne fortune de posséder des relations dont les auteurs non seulement ont été mêlés aux événements qu'ils racontent, mais y ont tenu parfois le premier rôle.

Tels sont le "*Discours du voyage fait par le capitaine Jacques Cartier aux Terres-neuves de Canada*, etc., en 1534; le *Brief récit et succincte narration*, etc., qui décrit le voyage de 1535; *les Voyages de Champlain*; *l'Histoire de la Nouvelle-France* de Lescarbot; *l'Histoire du Canada* et le *Grand Voyage au pays des Hurons* du frère récollet Gabriel Sagard Théodat; les *Relations* du Père Biard, en 1611 et 1616, sur les établissements de l'Acadie.

Malgré ma longue intimité avec les livres, je ne m'aventurerai pas à disputer sur les différentes éditions. La bibliographie est une mer semée d'écueils où seuls les spécialistes peuvent se frayer une voie—et pas toujours sans danger." [2] D'ailleurs, ce qu'il faut au travailleur, c'est un texte fidèle, authentique, fût-il récent et imprimé sur papier à envelopper la chandelle. Même, en ce cas-ci, il y aurait double avantage: ménager les petites bourses, toujours nombreuses parmi les lettrés, et vous permettre, au lieu d'un travail ennuyeux de copie, de déchirer un feuillet pour enrichir votre manuscrit. Quand on est son propre secrétaire, comme il arrive ordinairement *in nostro docto corpore*, hé bien, c'est une aubaine. Ainsi procédait, dit-on, le célèbre Rohrbacher—c'est peut-être une calomnie? mais comme il n'opérait pas toujours sur ses propres livres, il était devenu plus redoutable aux bibliotèques que les souris et les vers.

Pour nos vieux auteurs, nous n'en sommes pas là. Nous avons des éditions qui, tout en se présentant avec les grâces d'une belle impression, sur beau papier, ne sont cependant ni trop rares ni trop chères. La plupart nous viennent de la librairie Tross, à Paris, qui les a fait exécuter par différents imprimeurs.

En 1863 paraissait d'abord le *Brief Récit*, etc., du second voyage de Cartier d'après la rarissime édition de 1545. En 1865, le *Discours*

[2]Une preuve se trouve dans l'édition, faite par M. Thwaites, de la *Nouvelle Découverte* du P. Hennepin. Chicago, McClurg & Co., 1903. M. Paltsits, pp. xlvl, S.S., qualifie de futiles les essais de bibliographie du célèbre moine voyageur tentés per des hommes comme Shea, Justin, Windsor, le Dr. Dionne et Phileas Gagnon.

du voyage, etc., de 1534 était publié sur une édition de 1598, puis réédité, deux ans plus tard—1867—d'après un manuscrit de la bibliotèque impériale.[3] Entre temps avaient successivement paru six volumes de Sagard, de 1865à 1866, et trois de Lescarbot, 1866.

Ces éditions, sans être en fac-similé, répondent aux exigences de la science historique, reproduisent le texte original avec son ortographe archaïque et sa pagination indiquée à la marge. Pour Sagard surtout, qui n' avait jamais été réédité et qui, pour la période qu'il raconte, est un témoin de premier ordre, ces réimpressions étaient un service inappréciable rendu à notre histoire.

Quant aux *Voyages de Champlain*, plus importants encore, c'est un érudit canadien, versé autant, sinon plus, qu'homme du monde dans l'histoire du Canada, l'abbé Laverdière, qui nous en a donné, sous le patronage de l'Université Laval, une édition vraiment à la hauteur de l'oeuvre (1870). Elle se fait rare; cependant les amateurs peuvent encore la trouver sans trop de peine—moyennant finances.[4]

Si l'on ajoute à ces textes la monumentale édition des *Relations des Jésuites avec documents connexes*, publiée en soixante-treize volumes, de 1897 à 1901, par les frères Burrows, à Cleveland, Ohio, sous la direction de M. Reuben Gold Thwaites, on aura un outillage, sinon complet, du moins suffisant pour une étude approfondie des commencements de la Nouvelle-France au point de vue religieux et civil; on pourra se faire une opinion personnelle et motivée de quelques problèmes fort intéressants propres à cette ancienne époque, et dont nous dirons incidemment un mot en appréciant nos vieux auteurs: Quels ont été les premiers prêtres qui sont venus dans notre pays? Où et quand la première messe, la première église?

Parmi les sources de notre histoire primitive, nous n'avons nommé ni le P. Chrestien Leclercq, ni son confrère, l'auteur de *l'Histoire Chronologique de la Nouvelle-France.* Sont-ils donc—surtout le P. Leclercq—des auteurs à dédaigner? Point du tout. Et même, dans cet essai d'appréciation historique nous allons leur accorder la première place. C'est-à-dire, qu'au lieu de commencer par les temps les plus anciens, nous allons commencer par les plus rapprochés de nous,—procéder à la manière des écrévisses, ou de maitre Martin descendant d'un arbre, *poupe* en avant. La méthode au moins sera originale.

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[3]Dionne, *Jacques Cartier*, pp. 219, 221.

[4]La *Champlain Society*, de Toronto, en prépare une réédition. Cette société a déjà publié Lescarbot, Denys, la *Relation de la Gaspésie* du P. Leclercq, avec traduction anglaise, etc.

II

Du P. Chrestien Leclercq, nous avons deux ouvrages, publiés tous les deux en 1691: *Le Premier établissement de la Foy* et *La Nouvelle-Relation de la Gaspésie*.[5]

En 1890, une traduction anglaise, suivie d'un texte français soigneusement reproduit, a été donnée, de la *Nouvelle Relation*, par M. Ganong, pour la Société Champlain.[6] Mais le *Premier établissement de la Foy*, sauf une traduction anglaise due à M. John Gilmary Shea, en 1881, n'a jamais été reproduit, que nous sachions. Au dire de M. Thwaites, il aurait même été "supprimé dès son apparition,"[7] ce qui n'a pas dû contribuer à la diffusion de l'ouvrage. Il est devenu, en tous cas, une rareté bibliographique qui ne se trouve plus guère que dans quelques grandes bibliothèques. Nous avons eu l'avantage d'étudier l'exemplaire qui appartient au séminaire de Québec. Du commencement de février à la fin de juillet 1914, une couple de fois par semaine, pendant plusieurs heures chaque jour, commodément installé, grace à la bienveillance de notre excellent ami, Mgr. Am. Gosselin, alors Recteur de l'Université Laval, nous avons pu lire à loisir les deux volumes du *Premier établissement*, la *Nouvelle Relation de la Gaspésie*, et aussi, dans l'édition originale, *l'Histoire du Canada* de Sagard, que nous n'avions pas encore. Pour une simple lecture, c'eût été beaucoup trop de temps: les volumes sont de petite taille et les pages de taille plus petite encore.[8] Mais, comme il s'agissait de textes rares, nous avons voulu, afin de n'y pas revenir, en faire une étude approfondie, et même prendre copie textuelle des passages les plus remarquables. Nous pouvons donc en parler sans trop de témérité.

Le P. Chrestien Leclercq, récollet, envoyé en 1675 dans les missions de la Gaspésie, où il succédait à ses confrères, les PP. Hilarion Guesnin et Exupère Dethunes,[9] y a passé presque tout le temps de son séjour au Canada. Son unique absence est un voyage fait en France à la demande de ses supérieurs, afin d'obtenir des secours qui per-

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[5]Nous ne donnons que les mots esentiels. Les titres seuls ont plusieurs aunes de longeur.

[6]The *Champlain Society*, de Toronto.

[7]Réédition anglaise de la *Nouvelle Découverte* du P. Hennepin, Chicago, 1903. Introduction, p. XXXIV. Nous n'avons vu ce détail nulle part ailleurs.

[8]Comme, pour ces éditions rares, on donne le nombre des feuillets, nous pouvons faire remarquer—à ceux que le fait peut intéresser—que le premier volume du *Premier Etablissement* n'a que 454 pages, au lieu de 458, parce que la pagination saute de 452 à 457 sans crier gare.

[9]*Nv. Relation de la Gaspésie*, p. 22, éd. originale; *Premier Etablissement*, V. 11, p.—115, s.

missent d'établir un hospice à Québec pour les religieux et une maison à Montréal. Il apporte, en 1681, à M. Dollier, supérieur des Sulpiciens de Montréal, des lettres de l'abbé Tronson, supérieur du séminaire de Paris, qui accordent aux récollets "4 arpens de terre sur le bord du fleuve, proche la chapelle de la Sainte Vierge."[10] Il retourne ensuite à ses missions.[11] Ce dut être la même année, puisqu'il y avait passé six ans avant son voyage et que, repassé en France en 1686, il nous dit qu'il a été douze ans missionnaire chez les sauvages.[12]

Ce sont ses travaux apostoliques, avec les dangers qu'il a courus, le succès de ses efforts, les insuccès aussi et les tentations de découragement, qu'il nous décrit dans sa *Nouvelle Relation.* Mais la plus grande partie de l'ouvrage est consacrée à la description des moeurs, des coutumes, des superstitions, du langage des Gaspésiens. Chose curieuse, la relation s'ouvre,—dédicace à part, bien entendu,—par le récit de la destruction de la mission de la Gaspésie, en 1690, "par les Anglais, Hollandais et Français rénégats." C'est une lettre du P. Jumeau, son confrère et successeur en ces parages, qui apporte au P. Leclercq la sinistre nouvelle.

La lecture de la *Nouvelle Relation* est intéressante et instructive, bien qu'il ne faille pas mettre une importance exagérée dans l'histoire des sauvages porte-croix,[13] ni une créance trop robuste dans les diableries du jongleur[14] qui fait "paraître les arbres tout en feu qui brûlent visiblement sans se consumer et donne le coup de mort à des sauvages fussent-ils éloignés de quarante à cinquante lieues, lorsqu'il enfonce son couteau ou son épée dans la terre et qu'il en tire l'un ou l'autre tout plein de sang, disant qu'un tel est mort, qui effectivement meurt et expire dans le même moment qu'il prononce la sentence de mort contre lui."

Ces merveilles à part—bien au diapason pourtant de notre siècle de spiritisme à outrance—, on est ici en présence d'un écrivain sincère, d'un témoin.

Il n'en va pas de même, pour le *Premier établissement de la Foy,* qui raconte notre histoire depuis l'exploration de Verrazano, en 1624, jusqu'à la victoire de Frontenac en 1690. Il est vrai que l'auteur passe à tire-d'aile sur les premiers temps et ne dit rien des établissements français en Acadie. La fondation de Québec est le premier grand événement qui fixe son attention, avec—et c'est tout naturel—

[10] *Nv. Rel.*, p. 570, s.
[11] *Ibid.*, p. 571.
[12] *Ibid.*, p. 30.
[13] Chap. XI.
[14] Chap. XIII, p. 334.

la venue des récollets en 1615. C'est ici, d'ailleurs, le principal objet de son livre, comme le titre même l'indique: *Le Premier établissement de la Foy dans la Nouvelle-France.* Jusqu'à quel point le titre est justifié, jusqu'à quel point l'auteur a droit d'écrire ironiquement quelque part: "C'est une gloire pour les récollets d'être les précurseurs des jesuites dans tous les pays et de préparer la voie à ces hommes apostoliques,"[15] on pourra le voir suffisamment au cours de cette étude.

Ce que nous nous contentons de dire en ce moment, c'est que ce livre n'est pas l'oeuvre d'un témoin, ni d'un contemporain. Non qu'il faille toujours, pour faire une bonne histoire, être contemporain des faits qu'on raconte, ou témoin oculaire: aucune histoire générale, à ce compte, ne serait possible. Mais on doit toujours s'appuyer sur les témoignages, les documents de l'époque. Que le P. Leclercq ait eu à sa disposition d'excellentes sources d'information, nous l'admettons volontiers et nous reconnaissons que, dans les parties purement historiques, sa narration a du prix. Mais c'est une règle de bonne critique historique qu'on doit préférer le récit d'un contemporain, d'un témoin oculaire surtout, aux dires d'un écrivain postérieur et éloigné du théâtre des événements—à moins que le premier ne se montre évidemment égaré par la passion. Et ainsi, pour les débuts de l'histoire du Canada, au P. Leclercq, nous préférons l'honnête Sagard, les lettres et relations des premiers missionnaires jésuites, et, par-dessus tout, l'observateur judicieux, le fidèle annaliste qu'est Champlain.

Par exemple, quand le P. Leclercq fait mourir le frère Pacifique en août 1618, je retiens la date donnée par Sagard—le 23 août 1619. Parfois le bon Père n'est pas d'accord avec lui-même. Ainsi dans la *Nouvelle Relation*,[16] il écrit: "Le P. Bernardin, un de ces illustres missionnaires, mourut de faim et de fatigues en traversant les bois pour aller de Miscou et de Nipisiguit à la rivière de Saint-Jean, à la Cadie, où ces Révérends Pères avaient leur établissement principal." Dans le *Premier établissement de la Foy*,[17] le P. Bernardin est devenu le P. Sébastien. Mais ceci n'est qu'un *lapsus* tout à fait pardonnable. Il y a des choses plus graves.

Le P. Leclercq nous affirme que les jésuites, en 1632, ont pris possession du couvent, de l'église des pères récollets à la rivière Saint-Charles, se sont servis de leur argenterie laissée en 1629—dans l'espoir du retour. Hé bien, j'aime mieux m'en tenir à la *relation* de 1632,

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[15]*Premier établissement*, ch. XV, vol. 1, p. 468.

[16]P. 204.

[17]Vol. I, p. 242.

où le P. Le Jeune, témoin hors de pair en l'occasion, nous dit[18] que le monastère des récollets était en pire état que le couvent des jésuites. Des deux bâtiments qui composaient ce dernier, l'un était à moitié brûlé, l'autre "dépouillé de ses portes et fenêtres qui avaient été ou brisées ou enlevées." Et c'est ici pourtant que se réfugièrent les jésuites. De l'église des récollets, pas un mot. S'était-elle donc évanouie? Il vaut mieux se demander si elle a jamais existé.

Le P. Leclercq nous dit bien, en parlant du lieu choisi par ses confrères pour leur couvent: "Ce fut donc en cet endroit que nos pères entreprirent de bâtir la première église, le premier couvent et le premier séminaire qui furent jamais dans ces vastes pays de la Nouvelle-France."[19] Plus loin, il ajoute que le P. Denis Jamet, nouveau supérieur, arrivé en 1620 avec des ouvriers, pousse si activement la construction commencée, le 3 juin de la même année, par le P. Dolbeau, que bientôt les religieux peuvent s'y loger. Ensuite "il fit accommoder durant l'hiver les dedans de l'église de sorte qu'elle fut en état d'être bénite le 25 mai 1621."[20]

D'autre part, dans la lettre du P. Jamet à Charles des Boves, vicaire général de Pontoise,[21] il n'est question que d'une pièce du corps de logis "Nous divisions le bas en deux; de la moitié, nous en faisons notre chapelle en attendant mieux." La lettre est du 15 août. Si, du 15 août, 1620, au 25 mai, 1621, on a construit, au couvent des récollets, une église en pierre—il s'agit d'une église en pierre—il faut avouer qu'on allait plus vite en besogne en ce temps-là qu'aujourd'hui.

Dans l'introduction—d'ailleurs très bienveillante—de sa traduction de la *Nouvelle Relation de la Gaspésie*,[22] M. Ganong nous dit que le P. Leclercq est "par tempérament porté à embellir et à exagérer les choses qui peuvent faire honneur à sa profession." En d'autres termes, il aime la panache, et dans son livre, sous d'humbles formules, il en donne maint exemple. Mais, dira-t-on, dans le cas présent, son récit est corroboré par le fameux mémoire de 1637."[23] N'y voit-on pas en effet que les récollets ont été les premiers missionnaires de la Nouvelle-France, y ont été les premiers la lumière de l'Evangile, y ont construit la première église, etc.?

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[18]Edit. Burrows, V, p. 44. Cf. aussi, pp. 58, 68, 216.

[19]*Premier établissement*, I, 58.

[20]*Premier établissement*, I, 58.

[21]Citée par Sagard, *Hist. du Canada*, I, pp. 68-75.

[22]Edit. de la *Champlain Society*, 1910, avec texte français à le fin. "He had a marked temperamental tendency to magnify and embellish matters which could be turned to account in his calling," p. 17.

[23]Publié par Margry, *Mémoires et documents*, etc. Vol. I, p. 3, ss., 1879.

Une remarque au sujet de ce mémoire souvent cité ne sera peut-être pas inutile.

La critique historique nous met en garde contre les panégyriques parce que, destinés à exalter la mémoire d'un homme, ils sont sujets à des prétéritions et à des exagérations qui s'accordent mal avec la sévérité de l'histoire.

Nous ne sommes pas ici en présence d'un panégyrique proprement dit mais d'un plaidoyer qui en tient légèrement. Il s'agit en effet d'obtenir pour les récollets l'autorisation de retourner dans leurs missions du Canada—et, à cette louable fin, on fait valoir leurs travaux. Qui?—Un récollet, sans doute: il nous semble donc qu'il faille accepter ce document *cum grano salis*. L'excellent Sagard, d'ailleurs, qui est de la maison, nous fournira lui-même un sel de valeur non suspecte.

Il arrive en 1623.—S'il y a au couvent des récollets, une église bâtie en 1620-1621, il a dû la voir, parce qu'il voit très clair. Dans son *Histoire du Canada*,[24] il nous décrit minutieusement le couvent des Pères: "Ressemblant plustost à une maison de noblesse des champs que non pas à un monastère de frères Mineurs, ayant été contraints de le bastir de la sorte, tant à cause de notre pauvreté que pour le fortifier contre les sauvages." "Le corps de logis est au milieu de la court, comme un donjon, puis les courtines et remparts faits de bois avec quatre petits bastions de même estoffe, aux quatre coins, eslevez de environ 11 ou 15 pieds du raiz chaussée sur lesquels nos religieux ont dressé des petits jardins à fleurs et à sallades, d'où ils peuvent aller à nostre chapelle bastie de pierres au-dessus de la maitresse porte du couvent."

Ce n'est pas clair comme de l'eau de roche,—du moins ces dernières lignes. Cette chapelle ainsi juchée au-dessus de la maîtresse porte ne laissait pas que de nous intriguer un peu. C'est tout de même autre chose que la pièce intérieure dont parle le P. Jamet. Mais qu'était-ce au juste? Où trouver quelque lumière? Dans le *Grand Voyage au pays de Hurons*?

C'était peu probable. On sait que le texte du *Grand Voyage au pays des Hurons* publié en 1632, est littéralement reproduit dans *l'Histoire du Canada*, publiée en 1636. Le bon frère Sagard se copie lui-même—et c'est bien permis; il y en a tant qui copient les autres sans le dire! S'il y a des différences entre les deux textes, c'est que certains détails, comme il arrive dans cette description de l'établissement des récollets, sont plus développés dans *l'Histoire* que dans le *Voyage*. Malgré cela, le texte du *Grand Voyage*, sur le point parti-

[24]Edit. Tross, p. 161, s. (164-165 de l'orig.).

culier que nous étudions, est moins obscur. Après les premiers détails, en tout semblables dans les deux ouvrages, on retrouve "les quatre petits bastions faits de mesme, eslevez environ douze à quinze pieds du raiz de terre, sur lequel[25] on a dressé et accommodé des petits jardins, puis la grand'porte avec une tour carrée au-dessus faicte de pierre, laquelle nous sert de chapelle."[26] Et voilà! Le monastère était entouré de remparts de bois, avec courtines, bastions, fossés formés naturellement par les replis de la rivière, et, au-dessus de la grand'porte de l'enceinte, il y avait une tour carrée en pierre,— à douze ou quinze pieds de hauteur. C'est cette tour que le mémoire de 1637 et le P. Leclercq, et ceux qui s'y sont fiés, veulent nous faire prendre pour une église. C'était tout au moins une église en l'air.

Si nous nous sommes attardés sur ce détail, c'est que sans doute il est fort intéressant pour celui qui étudie l'histoire de l'Eglise du Canada, de savoir quelle a été la première église de Québec,— si toutefois on ne veut pas accepter pour telle la petite chapelle de 1615. Mais nous avons surtout voulu montrer que pour cette période de notre histoire qui s'arrête à la prise de Québec em 1629, non seulement nous pouvons nous passer du P. Leclercq, mais encore qu'il est moins sûr que son humble confrère, le frère Sagard. Certes, il écrit mieux que Sagard. Il parle la langue de la bonne époque du XVII siècle, son récit est alerte et clair: pour employer une expression banale, il se lit comme un roman. Par contre Sagard a pour lui la bonhomie, la simplicité, le naturel et—l'honnêteté. Il n'enjolive pas, il ne brode pas, il peint sans prétention ce qu'il a vu. Ce n'est pas un styliste. Lui-même, d'ailleurs, nous le déclare: "On pourra dire que je devrais avoir emprunté une plume meilleure que la mienne pour polir mes écrits et les rendre recommandables, mais c'est de quoy je me soucie le moins."[27] Cependant son style n'est pas aussi négligé qu'il veut bien le dire: il est remarquablement correct et clair pour l'époque. Le bon frère sème son récit de réflexions primesautières et, comme il reste toujours près de la nature, il brosse sans en avoir l'air maint tableautin digne d'être encadré. Ainsi, non seulement au point de vue de l'information, mais même à ce point de vue du mérite littéraire, du plaisir et du profit que peut procurer une lecture, Sagard peut nous consoler de la rareté de son célèbre confrère. Mais il s'arrête à 1629 et Leclercq pousse son histoire jusqu'à 1690.

Examinons si c'est pour notre plus grand bien et pour sa plus grande gloire.

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[25]Il faut: lesquels.

[26]*Grand voyage*, etc., édit. Tross, I, 39 (56, éd. orig.).

[27]*Hist. du Canada*, I, p. 11.

Il n'y a pas, dans le *Premier établissement de la Foy*, d'autres divisions que les chapitres qui se succèdent sans interruption de sorte que le XVII ouvre le second volume. Si le premier se ferme avec le chapitre XV, cela est dû à des erreurs de numération. Le chapitre IX est répété et l'erreur se continue jusqu'au XIV^{me} qui reprend son véritable chiffre et s'en trouve bien, puisqu'il le conserve au chapitre suivant. Ainsi deux chapitres IX, deux chapitres XIV, pas de chapitre XIII; c'est un mauvais chiffre! Pas de chapitre XVI non plus.[28] Mais à defaut de grandes divisions typographiques, le sujet du livre se partage naturellement en trois parties: la première, dont nous avons parlé, comprend treize chapitres; la deuxième, de 1631 à 1671, époque du retour des récollets dans la Nouvelle-France, se compose des chapitres XIV-XVIII; et le troisième, de 1671 à 1790, qui traite d'abord des premiers travaux des pères après leur retour, puis des voyages et découvertes de Cavelier de la Salle, occupe le reste de l'ouvrage, chapitres XIX-XXVI.

Autant la première partie est d'une lecture agréable, autant la seconde est pénible, agaçante, révoltante parfois. L'auteur commence par relater les efforts des récollets en 1631, 1632, pour revenir au Canada, efforts sans cesse renouvelés toutes les années suivantes. C'est la matière de deux interminables et fastidieux chapitres de près de cent pages: CIV and XIV bis., pp. 417-514.

Certes, nous sommes le premier à regretter que les récollets ne soient pas revenus dès 1632. Nous professons la vénération la plus profonde, la plus sincère admiration pour les Joseph Le Caron, les Dolbeau, les Jamet, les de la Roche d'Aillon, comme du reste, pour les Lalement, les Garnier et les Bréboeuf. Que les héroiques missionnaires aient été évincés d'un champ de labeur qu'ils avaient cultivé les premiers, que l'illustre Père Joseph le Caron en soit mort de chagrin, nous le déplorons, nous en sommes profondément touché. Mais cette injustice, qui en a été la cause? Sans recourir aux Cent-Associés, qui y furent bien pour quelque chose, Richelieu, à lui seul, suffit à expliquer le fait. Lui qui confiait aux capucins, en 1632,[29] les missions de l'Acadie et qui ordonnait d'en exclure tous les autres missionnaires réguliers et séculiers,[30] pouvait bien en faire autant pour cette partie-ci de la Nouvelle-France. C'est d'autant plus probable que ces missions furent aussi offertes aux capucins avant d'être—sur le refus de ces derniers,—confiées aux jésuites.[31]

[28]Les erreurs de pagination ont été indiquées plus haut, p. 3.

[29]Rameau, *Une colonie féodale*, I, 77.

[30]Faillon, *Hist. de la Col. Fr.*, I, 280, note d'après les archives des affaires étrangères, Vol. Amérique, fol. 100 et 106.

[31]Rochemonteix, *Les Jésuites et la Nv.-France*, I, p. 182.

Quoi qu'il en soit—et ce n'est pas ici le lieu de discuter à fond ce point d'histoire—pour le P. Leclercq, l'obstacle au retour des récollets, ce sont les jésuites. Il ne le dit pas avec la belle impudence qu'y met l'auteur de *l'Histoire Chronologique de la Nouvelle-France.*[32] Mais il le croit fermement et il l'insinue en maint endroit. Les jésuites se disculpent par plusieurs lettres. Le P. Le Jeune écrit au gardien du couvent de Paris, le 16 août 1632; le P. Charles Lalement, au P. Baudron, le 7 septembre, 1637, et aussi au frère Mohier. "C'étaient là, dit le P. Leclercq, des preuves authentiques de leur sincérité qui ne laissèrent plus aucun doute de la vérité." Il l'écrit, mais il n'en croit rien. Il continue le long et ennuyeux récit des démarches et des déconvenues de ses confères. On touche au but "mais des gens plus fins et plus puissants que nous jouèrent si bien leur petit rollet"[33] que tout est à recommencer. On sent qu'il s'exaspère, sa plume devient acerbe, ironique, enfiellée. Quand ensuite il arrive aux travaux apostoliques des jésuites, on devine quel esprit l'anime. De l'héroique épopée des missions huronnes et de leur glorieux martyrologe, rien! Les *relations* elles-mêmes, publiées en France sous le nom des jésuites, ne sont vraisemblablement pas authentiques: "J'ai toujours été persuadé, nous dit-il avec une feinte naiveté, que ne se faisant honneur que de leurs travaux et de leurs souffrances, les jésuites n'ont point de part aux Relations qu'on a imprimées du Canada, apparemment sur de faux mémoires, au moins en ce qui regarde l'avancement de la foy parmi les nations sauvages."[34]

Et alors, c'est entendu, tous ces récits de conversions, de néophytes dont la piété rappelle la ferveur des premiers chrétiens, sont de pieuses inventions "des contes," comme dit crûment *l'Histoire chronologique.*[35] 'On apprenait avec une agréable surprise, par les amples relations imprimées, les grands progrès de l'Evangile dans ces pays . . . O Dieu! quels empressements ces heureux succès faisaient naître dans le cœur de toute la province pour aller prendre part à de si merveilleux changements; s'ils étaient aussi véritables qu'on les débitait; car dans ce temps toute la France en était duppe."[36]

"Plut à Dieu, écrit-il encore, que toutes ces églises des *Relations* fussent aussi réelles que le pays les reconnaît chimériques!"[37]

Les travaux des récollets, par exemple, n'avaient pas eu cet insuccès!

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[32]P. 168.

[33]*Prem. établissement*, etc., I, p. 465.

[34]*Op. cit.*, I, 522.

[35]P. 4.

[36]*Op. cit.* I, 445. V. aussi 337, s. 527 ss.

[37]*Ibid.*

'Ce n'est pas, dit le P. Leclercq, que les petites églises naissantes que nous y avons laissées se soient démenties, à l'exception de deux ou trois ' . . . Il faut cependant "espérer que Dieu leur aura fait la grace de se reconnaitre quoique certains écrivains les aient damnés de plein droit."[38]

Ainsi les jésuites n'avaient pu faire en cinquante ans, ce qu'en quinze, avaient fait les récollets.

De cette partie du *Premier établissement de la foy*, où le faux le dispute à l'odieux, John Gilmary Shea a dit: "Aucun missionnaire n'a pu l'écrire, ou, s'il l'a fait, il doit se résigner à prendre rang au-dessous de Hennepin—No missionary ever could have written this part, or, if he did, he must be content to rank below Hennepin. '[39]

Au-dessous de Hennepin, généralement considéré comme un plagiaire, un faussaire et un menteur, ce n'est pas bien haut dans l'opinion du célèbre historien américain, qui ajoute d'ailleurs: "Cette seconde partie ne peut être considérée comme historique.—The second part, then, is not to be considered as historical." [40]

M. Ganong, il est vrai, cherche à se persuader et à persuader aux autres qu'elle n'est pas l'oeuvre du P. Leclercq.[41] Il s'appuie sur des différences de style. Mais, comme il n'a lu que la traduction de Gilmary Shea, il n'est pas en bonne posture pour faire de la critique interne.

Shea, d'autre part, qui note avec soin les anomalies, les faussetés, les injustes assertions du *Premier établissement de la foy*, rappelle,—sans y croire, bien entendu—une prétention du P. Hennepin. D'après le trop fameux voyageur, le livre aurait été publié sous le nom emprunté du P. Leclercq, par le P. Valentin le Roux, et la relation du P. Zénobe Membré qui y est publiée, ne serait que son propre journal —à lui, Hennepin,—qu'il avait laissé entre les mains du P. le Roux, à Québec.[42] Sans s'arrêter à ces affirmations que personne ne prendra jamais au sérieux, il demeure établi, en bonne critique historique, qu'un ouvrage publié au vu et su d'un écrivain et sous son nom, sans protestation de sa part ni d'autre, doit être tenu pour son oeuvre.

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[38]*Ibid.*, 461, 462. Ce trait est à l'adresse de Champlain qui dit clairement que les fameux convertis, Napagabiscou, Nanéagachit et Pastedechouan (Pierre-Antoine), ne persévérerènt point. Oeuvres, VI, 137 (1121). Pour ce dernier, nous avons le récit de sa triste mort dans la relation du P. Le Jeune—Ed. Burrows, IX. 69, 71.

[39]*Discovery and exploration of the Mississippi Valley*, 2de édit. Albany, N.Y., McDonough, 1903, p. 95. La 1re éd. est de 1852.

[40]*Ibid.*, p. 86.

[41]*Nv. Relation de la Gaspésia.* Introduction, p. 20, s.

[42]*Loc. cit.*, p. 83.

Quant à la supposition que la seconde partie serait d'une autre main que les deux autres, outre qu'elle est refutée par la règle de critique qu'on vient d'énoncer, elle est encore gratuite: pour celui qui lit attentivement l'ouvrage entier, il n'y a pas à douter que la même main n'ait partout tenu la plume.

Au P. Lercleq, il faut donc attribuer ce qui est bon—et il y en a beaucoup—, et ce qui est mauvais—et il y en a plus encore.

Au commencement de la troisième partie se trouvent plusieurs détails intéressants: construction, à N.-D.-des-Anges, d'un bâtiment pour servir de chapelle, et où Mgr de Laval dit la première messe le 4 octobre 1671,[43] fête de S. François; la pose de la première pierre de l'église du couvent, le 22 juin 1671, par l'intendant Talon,[44] les travaux artistiques du frère Luc Lefrançois "assez connu de toute la France pour un des plus habiles peintres de son temps" et qui orne de ses tableaux, outre l'église et la chapelle des récollets, la paroisse de Québec, l'Hôtel-Dieu, les églises des jésuites, de l'Ange-Gardien, du Château-Richer, de la Sainte-Famille, à l'île d'Orleans;[45] le commencement des missions de la Gaspésie en 1673.[46]

Mais l'objet principal, ce sont les voyages de Cavelier de la Salle. Bien qu'il y ait eu un P. Leclercq[47] parmi les compagnons du célèbre et infortuné explorateur, ce n'était pas le nôtre, et celui-ci, pour sa narration, a utilisé ou même textuellement reproduit le journal du P. Zénobe Membré et la relation du P. Anastase Douay. Il s'y trouve une attaque contre la véracité du journal du P. Marquette qui, avec Joliet, avait eu le tort de découvrir le Missisipi avant la Salle. Le P. Marquette n'est pas nommé—il est rare que le P. Leclercq attaque franchement,—il préfère les insinuations—, seul Joliet a l'honneur d'être considéré comme un faussaire. Il est entendu que sa relation "qui de fait n'est pas donnée sous son nom" ne contient "pas un mot de vérité" et a été "imprimée sur de faux mémoires."[48] Hélas! retour des choses! Joutel, dans son "*Journal du dernier voyage du sieur de la Salle*, en dira autant des relations sur lesquelles se fonde l'auteur du *Premier établissement de la foy*!"[49]

Néanmoins on ne révoque pas en doute la véracité des relations du bon P. Membré et du P. Douay. Le P. Membré, comme le P. de

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[43]Vol. II, p. 92.

[44]*Ibid.*, p. 94.

[45]*Ibid.*, 96.

[46]*Ibid.*, 103.

[47]Le P. Maxime Leclercq, frère du P. Chrestien, d'après les RR. PP. Hugolin et Odoric. V. Ganong—*Nv. Relation de la Gaspésie.* Introd., p. 3, note 5.

[48]*Premier établissement*, II. 364, ss. Shea, *Discoveries*, éd. citée, p. 227.

[49]Margry, *Op. cit.*, III, pp. 190 s, texte et note.

la Ribourde, comme la Salle lui-même et bien d'autres, a laissé ses os là-bas en témoignage de sa sincérité.

Tous ces récits sont du plus grand intérêt, et vraïment, s'il n'y avait que le P. Leclercq pour nous en fournir le texte, il faudrait souhaiter qu'on le réimprime. Mais ils ont été traduits et édités par Shea, en 1852, avec le journal du P. Marquette, les relations du P. Allouez, s.j. et du P. Hennepin, et réédités avec l'ouvrage entier en 1881. En 1861, le même érudit a publié les relations de l abbé Cavelier, frère de la Salle, des abbés Saint-Cosme et Le Sueur et du P. Guignas. Pour continuer la même série, paraissait, en 1884, le journal de Joutel, dé à publié par Marguy, en 1879, avec les lettres de la Salle et beaucoup d'autres documents relatifs à la découverte du Mississipi. Nous avons donc sur cette question une documentation copieuse, de sorte que cette partie du livre du P. Leclercq, la plus importante de son oeuvre,—où, du reste, il a surtout joué le rôle de compilateur,—tout en étant fort intéressante,—n'est pas nécessaire.

En résumé, sur trois parties, deux ne sont pas indispensables au travailleur, et l'autre n'aurait jamais du voir le jour.

Cette conclusion peut s'appliquer—*a fortiori*—à *l'Histoire chronologique de la Nouvelle-France*, que nous avons citée plus haut.

C'est à l obligeance vraiment excessive de M. Eugène Réveillaud que nous devons cette vieille histoire qui dormait dans les cartons de la Bibliothèque nationale, à Paris, d'un sommeil deux fois séculaire qu'il eût mieux valu ne jamais interrompre. Mais quand on se nomme M. Réveillaud, évidemment ce n'est pas pour rien.

De cet honorable personnage, nous ignorons les destins. Habite-t-il encore notre monde sublunaire? Est-il allé rêver sur les rives sombres du Styx? Nous ne savons,—c'est pourquoi nous en parlons au passé.

Il nous avait déjà gratifiés, en 1884, d'une *Histoire du Canada.* Elle est dédiée à "Jules Ferry, Président du Conseil des Ministres, etc., comme témoginage de la reconnaissance d'un Français pour la double oeuvre accomplie sous son gouvernement, de l'instruction nationale généralisée," etc., etc.

Ainsi M. Réveillaud dédiait son livre à l'auteur des lois scélérates contre les écoles catholiques de France, et la raison—une des raisons—de cette dédicace, c'était cette oeuvre de sectaire étroit et malfaisant! Pas besoin de dire dans quel esprit a été conçue la nouvelle *Histoire du Canada.* L'auteur était huguenot et cela se voit tout de suite. Il lève une antienne à la gloire de ce grand Français qu'était Coligny, et en l'honneur des "huguenots du XVI siècle (qui) étaient parmi les plus valeureux, les plus entreprenants, les plus éclairés et les plus industrieux des enfants de la France."[50] Partant, Richelieu eut grand tort de leur faire la guerre et de leur fermer les portes de la Nouvelle-France.[51] Ce n'est pas ce que pensait Champlain, ni Sagard, ni Leclercq, ni même l auteur de *l'Histoire chronologique*. Mais M. Réveillaud pensait ainsi. Naturellement il ne peut manquer de s'élever contre les émpiètements du clergé catholique. Qu'évêque et missionnaires, pour défendre la foi et même l'existence de leurs néophytes, se soient ligués contre la traite néfaste de l'eau-de-vie, c'est de la tyrannie cléricale. Pourtant, M. Réveillaud qui, en sa qualité de calviniste, devait régler sa foi sur l'Ecriture, ne pouvait ignorer la parole des Saints Livres: La justice grandit les peuples, l'iniquité les rend malheureux.[52] Alors, comme aujourd'hui, c'est ce que prêchait le clergé. Si les jésuites n'avaient été le but de quelques traits choisis, c'eût été merveille. On cite contre eux quelques-uns des pages les plus venimeuses de Michelet:[53] "Les Jesuites, rois du Canada, avaient là de grands biens, une vie large, épicurienne (jusqu'à garder de la glace pour rafraîchir leur vin l'été). Ce séjour était commode à l'ordre qui y envoyait d'Europe ce qui l'embarrassait, parfois des saints idiots, parfois des membres compromis qui avaient fait quelque glissade,"[54] etc.

Quand on met ces accusations fantaisistes en face de la réalité bien connue, on ne peut s'empêcher de déplorer les excès lamentables auxquels peuvent être entraînés par la passion religieuse, même de bons esprits. Cela va parfois jusqu à l'hallucination, comme chez Villemain.[55]

Féru de cette belle doctrine, il arriva que M. Réveillaud découvrit, en 1888, à la Bibliothèque nationale, un manuscrit de 1689 intitulé *Histoire de la Nouvelle-France*, sans nom d'auteur. Par la comparaison avec d'autres manuscrits, il crut pouvoir publier l'ouvrage sous le nom du P. Sixte le Tac, récollet, missionnaire au Canada dans le même temps que le P. Leclercq, qui en fait mention en 1678: "Ce fut dans cette même année (1678) que le P. Xiste le Tac qui occupait la mission des Trois-Rivières, y fit aussi bastir une maison sur nostre

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[50]P. 28.

[51]Pp. 78, 90.—A la page 195, on apprend que le marquis de Beauharnais, notre gouverneur, était un bâtard de Louis XIV, chose généralement ignorée—ou du moins passée sous silence par nos historiens.

[52]Prov. XIV. 34.—*Justitia elevat gentes; miseros autem facit populos peccatum.*

[53]P. 67, en note, et p. 97.

[54]*Hist. de France*, XVII, p. 180.

[55]Homme d'état, écrivain illustre; la peur des jésuites l'a rendu fou! V. Mourret: *Hist. de l'église*, VIII, p. 293, note 2; Thureau-Dangin: *Hist. de la Monarchie de juillet*, V. p. 546.

terrain par les petites contributions et les secours que le révérend père commissaire lui envoyait de nostre couvent de Nostre-Dame-des-Anges." [56]

Que *l'Histoire chronologique* soit du P. Sixte le Tac, c'est grand dommage pour lui. Mais nous n'avons pas les renseignements voulus pour discuter cette attribution. D'ailleurs, elle n'a été, que nous sachions, contestée par personne. Ce qui n'est guère contestable, c'est que l'auteur soit un récollet. Toutefois, pour la besogne qu'il a conscience de faire, il sent le besoin de cacher son identité. Il se présente comme un militaire auquel "le pays stérile en affaires de guerre dont (il) fait profession" laisse des loisirs pour lire et écrire l'histoire.[57]

Il va sans dire que ceux qui l'ont écrite avant lui, "Sagard, Champlain, Lescarbot, Lecreux (*sic*: Ducreux-*Creuxius*)" sont obscurs, "remplis d'histoires de voyages, de rivières, de lacs, d'anses qui ne font qu'embrouiller."[58] Lui va nous donner la vraie histoire! Vous pouvez y compter, car c'est un observateur d'une perspicacité rare. Il a remarqué qu'au Canada "les terres ne sont bonnes qu'à certains endroits et (que) le bois n'y est pas de conséquence vu qu'il n'est pas assez cuit par le soleil, ce qui fait qu'il n'est pas fort propre à bâtir des navires."[59]

Quant aux sauvages, ils sont si méprisables, "ils entrent même si peu, dit-il, dans la connaissance de notre religion que je ne sçaurais m'empêscher de me fascher lorsque je vois les livres farcis de contes que l'on fait d'eux pour tromper le public." [60]

L'excellent homme!

Sur ce texte, M. Réveillaud fait remarquer que c'est une pointe contre les jésuites. C'est du moins une grosse pointe qu'il faudrait aiguiser un peu.

Ensuite sont racontés les événements qu'on trouve partout, mais non sans quelques erreurs. Ainsi le P. Sixte le Tac, si c'est lui qui a commis cette histoire, fait aller Sagard chez les Hurons en 1623[61] et le

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[56]*Premier établissement*, II, 126, 127.

[57]Pp. 1, 2.

[58]*Ibid.*, p. 3.

[59]*Ibid.*

[60]Le P. Leclercq est plus juste quand il écrit: "C'est une erreur qui n'est que trop commune . . . que les peuples de l'Amérique septentrionale, pour n'avoir pas été élevés dans les maximes de la civilité, ne retiennent de la nature humaine que le seul titre d'hommes sauvages et qu'ils n'ont aucune de ces belles qualités de corps et d'esprit qui distinguent l'espèce humaine. *Nv. Rel. Gasp.*, p. 31, 32.

[61]P. 118.

fait repasser en France en 1624,[62] alors que, d'après Sagard lui-même, qui devait en savoir quelque chose, il faut respectivement 1624 et 1625.

Le manuscrit s'arrête au commencement de la deuxième partie, au moment où les récollets, évincés de la Nouvelle-France, multipliaient les démarches et les requêtes pour obtenir d'y retourner. L'auteur examine les raisons que l'on oppose et conclut que "c'estaient les pères jésuites,—qui avaient leur intérêt dans cette Compagnie de Marchands, vû qu'ils en avaient trois parts et qui voulaient mettre un évêque qui fût leur créature comme ils en mirent un en effet l'an 1657, qui est Mr de Laval,—que c'estait eux, dis-je, qui formaient opposition et qui faisaient agir les marchands sans qu'ils parussent eux-mêmes." [63]

Pour apprécier d'un mot *l'Histoire chronologique*, il n'y a qu'à dire: C'est du Leclercq deuxième manière et du pire.

L'éditeur heureusement a fait suivre le texte de plusieurs pièces d'archives intéressantes qui empêchent le volume d'être inutile.

III

Passer du P. Leclercq et du prétendu P. Sixte le Tac à Lescarbot et à Champlain, c'est, de toute manière, monter, et dans le temps et au double point de vue de la valeur des oeuvres et des écrivains.

De Champlain, nous dirons peu de chose, tant il est connu et tant l'éloge à son égard est grand et unanime. Il n'y a guère que l'abbé Faillon qui ait une légère tendance à le rabaisser au rang d'un simple traiteur, sans doute parce que Champlain, au lieu de Montréal, a eu le malheur de fonder Québec.

Pour montrer le mérite de Champlain, nous nous contenterons de citer un écrivain protestant, M. Kingsford: "Quel nom (dans notre histoire) a plus de grandeur? . . . Jugé par ses écrits, Champlain nous apparaît rempli d'une rare modestie, d'un souci constant de la vérité, de sorte que sa parole obtient créance immédiate. Il ne sacrifie pas la réalité à l'effet. Nous avons chez lui un tableau clair et complet de tous les événements de son temps."[64]

L'auteur pousse l'admiration pour son héros jusqu'à le comparer à César! parce que tous deux ont été "hommes d'action et hommes de lettres."[65] Ce parallèle est rempli de bonnes intentions, mais c'est

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[62]P. 120.
[63]P. 168.
[64]*History of Canada*, Toronto, 1887....1898, en dix vol. Vol. I, p. 137.
[65]*Ibid.*, 136.

un exercice littéraire qui prête ici un peu à rire. La simple pensée de rapprocher le grand capitaine, l'ambitieux général qui disait: "Plutôt le premier dans cette bicoque que le second dans Rome!" du modeste Champlain dont tous les exploits se résument à quelques coups d'arquebuse contre les Iroquois, est tout à fait comique et il ne faudrait pas s'y arrêter en un moment où le sérieux est de rigueur. Que César ait bu de l'huile rance sans faire la grimace, comme Champlain avalait de la sagamité, pour ne pas faire peine à son hôte, c'est le propre d'une bonne âme. Vous en feriez autant!

Quant à l'écrivain, hé bien, vraiment Champlain écrit une langue singulièrement claire et même élégante pour son temps. Mais ce n'est pas César, non, ce n'est pas César, et....sauf ce point de vue littéraire ....tant mieux pour lui, à tous égards!

L'admiration entraîne M. Kingsford plus loin encore. Il veut qu'il ait été protestant! L'éminent abbé Faillon....ou ne laisse pas, pour quelques peccadilles, d'avoir du mérite....avait déjà émis un doute de ce genre, au moins sur l'origine calviniste de Champlain.[66] Pour l'historien ontarien, il n'y a pas de doute. Il écrit sans sourciller: "Il est de toute évidence que Champlain était protestant—All evidence points to the certainty that Champlain was a protestant."[67]

Et pourquoi, de grâce? Parce que....c'est la principale raison ....il se nommait Samuel et que les catholiques n'avait pas le coutume de donner à leurs enfants des noms tirés de l'Ecriture.

Et voilà pourquoi votre fille est muette! Qui d'entre nous n'a connu....sans parler des Rachels et des Judiths, des Esthers et des Rebeccas....nombre d'Israels, d'Isaacs, de Banjamins, d'Isaies, de Jérémies, etc., tous rejetons de bonnes souches catholiques plantés dans les jardins de la sainte Eglise par les plus orthodoxes des curés? Il suffit du caprice ou de la sottise d'un parrain, surtout d'une marraine, pour affubler un enfant d'un de ces noms dont plus tard il ne sait que faire.

Mais, dit-on, l'acte de naissance de Champlain n'a jamais été retrouvé dans les registres catholiques "pourtant si bien tenus"—merci du compliment—L'a-t-on trouvé dans les régistres calvinistes? Et Monseigneur de Laval et Jacques Cartier? et Sagard? et Lescarbot? et tant d'autres peuvent-ils nous fournir leur acte de naissance? Parfois, pas même la date de leur mort. Une note à la marge d'un régistre nous apprend par hasard celle de Jacques Cartier (1557).[68]

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[66]*Hist. Col. Fr.* I, 550.

[67]*Op. cit.* I, p. 18, s.

[68]N. E. Dionne: *Jacques Cartier.* Q. 1889, p. 165.

On a dépouillé Champlain de plusieurs choses. On lui enlève la particule et il semble qu'on ait raison, parce que Lescarbot, son compagnon à Port-Royal, écrit: *Le capitaine Champlein.* Au reste, c'est bagatelle, puisque cette particule n'implique pas du tout la noblesse de race et que Champlain est assez grand pour commencer sa propre noblesse. On lui ôte maintenant....et c'est un peu plus grave....son portrait traditionnel. Quand nous disons traditionnel, il s'agit d'une jeune tradition; elle ne remonte qu'au milieu de l'autre siècle. C'est en effet vers 1854 qu'un graveur parisien, Ducornet, publia une lithographie, prétendue reproduction d'un portrait de Champlain par Moncornet, au XVII siècle, conservé à la Bibliothèque nationale.

Or parmi les Moncornets de la célèbre bibliothèque, Champlain brille par son absence! Mais il y a un Michel Particelli qui lui ressemble comme un frère. Pour s'édifier sur ce point....sur cette fumisterie....il n'y a qu'a voir l'article de M. Biggar dans la *Canadian Historical Review,* fascicule de décembre 1920.[69] Ainsi ce portrait qui cadre si bien avec ce que nous savons du Père de la Nouvelle-France, qui nous le montre calme, grave, d'un poids assez imposant pour écarter toute idée de pétulance, ce portrait est un faux! Hé bien, nous y renonçons volontiers, ainsi qu'à tous les faux portraits qui ornent notre galerie historique, nous souhaitons même qu'un iconoclaste érudit y porte quelque jour, par amour de la science, une flamme et un fer destructeurs.

Mais ce à quoi nous ne pouvons renoncer, chez Champlain, c'est à sa qualité, à sa foi de catholique. D'ailleurs, Champlain....nonseulement si pieux mais si zélé catholique,....Champlain protestant! C'est vraiment une des plus jolies inventions historiques de la fin de l'autre siècle. Il est bon, tout de même, en lisant l'histoire de trouver de ces perles.[70] Elles reposent des études sérieuses: c'est une agréable détente.

Une question....beaucoup plus importante que tout cela....se pose au sujet de l'édition des voyages de Champlain faite en 1632.

Tout lecteur peut s'apercevoir qu'elle diffère notablement en certaines parties des éditions de 1613 et de 1619. L'abbé Laverdière dans son introduction, p. VII, fait remarquer qu'on retranche tout ce

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[69]Publication de l'Université de Toronto, p. 379, S. M. Bigger s'inspire de M. Paltsits, dans *l'Acadiensis,* Vol. IV, pp. 306-311.

[70]M. Kingsford a de ces trouvailles. Ainsi, il nous dit que la lettre K n'existe pas en français et que c'est pour cela que David Kirke, dans sa lettre à Champlain, sgne: *Quer* qui était la forme du nom de sa famille quand elle résidait à Dieppe. En note, *op. cit.* Vol. I, p. 88.

qui dans l'édition précédente, a trait à l'arrivée et aux travaux des récollets.

"Il est évident, dit-il, qu'une main étrangère s'est chargée de la révision de l'ouvrage de Champlain."

Et comme en 1632 les jésuites revenaient seuls au Canada, il semble que cette main étrangère ait été celle d'un jésuite. "De sorte que, tout bien considéré, ajoute le très érudit éditeur, il semble que l'édition de 1632 n'ait pas été faite ou surveillée par l'auteur lui-même et de plus qu'elle ait été confiée à un père jésuite ou à un ami de leur ordre.[71]

Pour confirmer cette conjecture....ce n'est rien autre chose.... il ajoute quelques inexactitudes typographiques et enfin le chapitre premier du livre III[72] où sont racontés, d'après le P. Biard, les essais de Poutrincourt en Acadie, de 1610 à 1613, les travaux des jésuites, la fondation de la petite colonie de Saint-Sauveur et la ruine de tout par Argall en 1613. Ce qui est simple conjecture chez l'abbé Laverdière est devenu certitude pour l'entreprenant M. Kingsford....et il part de là pour nier plusieurs faits rapportés dans l'édition de 1632: Ainsi la conduite de Thomas Kirke dans son combat avec Emery de Caen, le larcin d'un calice par Louis Kirke, l'altercation du blasphémateur Michel avec le P. de Brébeuf et sa mort assez semblable à un châtiment céleste, etc.

N'en déplaise au sévère historien, et toute révérence gardée à l'égard de l'érudit abbé Laverdière, il nous semble que la règle de critique historique que nous avons rappelée[73] au sujet du P. Leclercq doive trouver encore ici son application: "Un ouvrage publié au vu et su d'un écrivain et sous son nom, sans protestation de sa part, ni d'autre, doit être tenu pour son oeuvre." Ce n'est, d'ailleurs, que l'expression du simple bon sens. Champlain était en France en 1632, il a vécu jusqu'à 1635. Ces changements dans son texte ont-ils pu lui échapper? Les a-t-il désavoués? Non, non. Donc son autorité couvre cette édition comme les précédentes.

On n'y mentionne que sommairement les récollets: Champlain arrive en 1615 avec "quatre Religieux."[74] C'est peu, mais d'autres faits non sans importance sont aussi retranchés. Par exemple la conspiration du serrurier Jean du Val. Faudra-t-il dire qu'un serrurier, pour l'honneur de la profession, a escamoté ce récit?

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[71] *Voyages de Champlain*, V, p. 242 (898), note 1.
[72] Vol. V, pp. 109-126 (765-782).
[73] *Supra*, p. 8.
[74] Oeuvres, V, 241 (897).

Quant à ce qui est ajouté sur l'Acadie[75] nous demandons s'il n'était pas bien naturel que Champlain, qui avait raconté les débuts de ces établissements, aimât à en redire les développements et la ruine? D'ailleurs il s'y était trouvé intimement mêlé par les démarches qu'il avait faites auprès de Madame de Guercheville et du P. Coton pour obtenir que les largesses destinées à fonder St-Sauveur fussent plutôt employées à développer Québec. Et à qui pouvait-il emprunter les détails de son récit mieux qu'au P. Biard témoin oculaire et digne de foi? Et, du reste, rien ne démontre qu'il n'avait pas d'autres sources d'information. Lescarbot ne lui était pas un inconnu! Et tout le chapitre est tout à fait dans sa manière, et comme la réflexion finale est bien de lui! "Voilà comment les entreprises qui se font à la haste et sans fondement, et faistes sans regarder au fond de l'affaire, réussissent tousiours mal."[76] Un jésuite n'aurait pas écrit cela d'une entreprise dont le P. Coton et ses confrères avaient été les principaux conseillers et les acteurs avant d'en être les victimes.

Et quelle était la meilleure place pour ce chapitre? Absolument celle qui lui a été assignée: on en chercherait en vain une autre. C'est l'ordre logique: Champlain achève de décrire les destins de l'Acadie avant de raconter la fondation de Québec.

Sa transition: "Retournons et poursuivons la seconde entreprise du sieur de Monts," pouvait être plus élégante; elle ne saurait être plus claire.

Nous concluons donc que, à notre avis, l'édition de 1632, pour ce qu'elle rapporte, mérite la même confiance que les deux autres.

IV

L'autorité de Marc Lescarbot n'est pas aussi incontestée que celle de Champlain.

Peu d'historiens ont été plus discutés que lui. Les uns l'ont loué sans restriction, comme Charlevoix, personne ne lui a été plus sévère que l'abbé Faillon. Pour l'un, c'était un bon catholique, pour l'autre, un huguenot, pour un troisième, il était catholique de nom et huguenot de cœur.[77] Mais tous s'accordent à reconnaître en lui un observateur attentif et judicieux et à dire que, au point de vue matériel, sa présence a été pour Port-Royal une bonne fortune.

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[75]Nous ne disons rien des erreurs typographiques. Il s'en trouve, comme on dit, dans les meilleures familles. Nous en avons cité plusieurs et d'assez fortes en parlant du P. Leclercq.

[76]Oeuvres V, 126 (782).

[77]Rochemonteix. *Les Jésuites et la Nv.-France*, I, 18, 19, notes.

Qu'on nous permette, après une lecture attentive, d'en dire, à notre tour, notre sentiment.

Quiconque ouvre son *Histoire de la Nouvelle-France*—il a écrit beaucoup d'autres choses—se trouve en présence d'un esprit d'une culture peu commune, auquel les auteurs anciens sont familiers. Poètes, orateurs, historiens, naturalistes, il les cite souvent et à propos; il cite même les Pères de l'Eglise. Le grec, l'hébreu ne lui sont pas étrangers. Il aime à philosopher sur tout un peu, et ses réflexions, pour n'être pas toujours d'une grande profondeur, manquent rarement de justesse. Citons comme exemple ce qu'il dit au sujet des colons de la Floride.[78] "Que s'ils ont eu de la famine, il y a eu de la grande faute de leur part, de n'avoir nullement cultivé la terre laquelle ils avaient trouvée découverte, ce qui est un préalable de faire avant toute chose à qui veut s'aller percher si loin de secours. Mais les Francais et préque toutes les nations du jourd'hui (j'entends de ceux qui ne sont pas nais au labourage) ont cette mauvaise nature, qu'ils estiment déroger beaucoup à leur qualité de s'adonner à la culture de la terre qui néanmoins est à peu près la seule vacation où réside l'innoncence. Et de là vient que chacun fuiant ce noble travail, exercice de nos premiers pères, des Rois anciens et des plus grands Capitaines du monde, et cherchant à se faire gentilhomme au dépens d'autrui . . . Dieu ôte sa bénédiction de nous," etc. –C'est aujourd'hui comme au temps de Lescarbot, au grand détriment et péril de la société.

Comme il a les yeux ouverts, qu'il sait bien peindre ce qu'il observe, que sa langue, sans être de la belle époque, est claire et pittoresque, on a avec lui, beaucoup à s'amuser et à s'instruire.

Pour prétendre qu'il était huguenot, il faut ne l'avoir pas lu, ou l'avoir lu d'une manière bien distraite. Partout, il se montre catholique. Avant son départ pour l'Acadie, en 1606, il cherche, et Poutrincourt avec lui, un prêtre pour accompagner les colons. Au défaut d'un prêtre, qui ne se trouve pas, Lescarbot aurait voulu au moins qu'on lui permit d'emporter l'Eucharistie, comme faisaient les premiers Chrétiens, et il cite l'exemple du frère de saint Ambroise, Satire, à qui elle avait été une grande consolation dans son naufrage. Il se montre étonné du refus qu'on lui oppose: "Car dit-il, l'Eucharistie n'est pas aujourd'hui autre chose qu'elle était alors, et s'ils la tenaient précieuse, nous ne la demandions point pour en faire moins

[78]Vol. II, p. 483—Notons une fois pour toutes, que, dans *l'Hist. de la Nv.-France*, la pagination se continue dans les trois volumes, formant 851 en tout (877 dans l'ancienne édition).

de cas."[79] C'est aller contre la discipline, mais pas du tout contre la foi catholique, bien au contraire!

Il est vrai qu'il blame les ecclésiastiques qui montrent peu de zèle pour le salut des âmes,[80] et que dans son *Adieu à la France* il écrit:

"Prélats que Christ a mis pasteurs de son Eglise. . . .

"Sommeillez-vous, hélas! Pourquoi, de votre zèle.

"Ne faites-vous pas paraître une vive étincelle.

"Sur ces peuples errans qui sont proye à l'enfer?"[81] etc. C'est dur, mais le bon frère Sagard l'est peut-être plus encore quand il écrit: "Toute la France bouillonne de Religieux, de Bénéficiers, de Pretres séculiers, mais peu se peinent pour le salut des mescroyants. Il y en a une infinité qui demeurent icy oysifs mangeans le bien des pauvres et courans les bénefices que s'ils passaient aux Indes et dans les pays infidèlles, y pourroient profiter et pour eux et pour autruy," etc.[82]

Or, personne n'a jamais en suspicion la foi du bon frère récollet. Pourquoi serait-on plus sévère pour Marc Lescarbot? Qu'il ait eu l'esprit caustique et frondeur, nous l'accordons volontiers. Il critique bien librement ce qui lui déplait, même chez les gens d'Eglise. Au moins ne nous donne-t-il pas le triste spectacle d'un religieux dénigrant l'oeuvre d'autres religieux. C'est un laïque, et, qui plus est, un avocat au parlement. Or, en France, Eglise et Parlements ont rarement fait bon ménage. On comprend très bien l'esprit de Lescarbot. D'ailleurs la vérité vraie, c'est que, sauf les passàges que nous avons indiqués, il n'y a rien de sérieux dans l'édition de 1611, que nous avons étudiée, contre les ecclésiastiques en général et contre les jésuites en particulier—qui sont à peine nommés en passant.

Mais il y a une autre édition!

C'est celle de 1617-1618, et nous sommes grandement obligés à la *Champlain Society* de l'avoir rééditée avec une traduction anglaise due à M. Grant, professeur d'Oxford, et une introduction de M. Biggar.

En étudiant l'autorité historique de Lescarbot, nous allons voir en quoi cette édition diffère des deux premières, de 1609 et 1611, et en quoi elle prête flanc à des critiques méritées et à une juste défiance.

Venu à Port-Royal en 1606 et retourné en France en 1607, Lescarbot n'a passé qu'un an en Acadie, et c'est précisément ce qu'il y a vu et fait qui forme la partie la plus neuve et la plus intéressante

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[79]P. 497.
[80]P. 495, 496.
[81]P. 488.
[82]*Hist. du Canada*, pp. 38 et 39.

de son histoire:—livre IV, chapitres IX-XVIII.[83] Pour tout le reste, il dépend d'autrui, et, naturellement, il vaut ce que valent ses sources d'information. Abstraction faite des établissements de la Floride et du Brésil, dont le récit est palpitant d'intérêt, mais ne nous touche pas, il exploite, pour la Nouvelle-France proprement dite, les relations des voyages de Cartier et les voyages de Champlain. Il reproduit même —du moins il le prétend—le texte des deux premiers voyages du capitaine malouin, l'un, 'd'après une édition imprimée, l'autre, d'après la manuscrit original présenté au Roy et couvert en satin bleu.''[84]

Remarquons cependant qu'il mêle parfois les récits de Champlain à ceux de Cartier. Ainsi les chapitres XIX, XXI, XXVIII du livre III appartiennent à Champlain. Dans toute cette partie, y compris l'expédition de Roberval, sur laquelle Lescarbot manque de renseignements complets—et celle du marquis de la Roche (chapitre XXXII) les deux éditions se ressemblent. De même encore pour les commencements de l'Acadie, livre IV, de 1604 à 1607.

Et vous voici au livre qui a obscurci la belle renommée de *l'Histoire de la Nouvelle-France*: c'est le livre V. Le VIème est resté le même en 1618 qu'en 1611. Il y a bien un chapitre de moins, mais comme, en 1618, les chapitres III et IV ont été fondus en un seul, la matière n'est pas changée.

Mais, en 1618, le livre V renferme quinze chapitres au lieu de six en 1611; Donc neuf chapitres nouveaux. On doit dire dix, parce que le chapitre sixième, de 1611, où il était question d'une société à la manière de Lescarbot, pour "planter la foy et le nom françois es terres occidentales et d'oultre-mer," a fort heureusement été retranché.

C'est dans ces chapitres supplémentaires que sont racontés les débats entre les jésuites—arrivés en Acadie en 1611—et Poutrincourt ou plutôt son fils, Charles de Biencourt.

Or, toutes ces difficultés, ces querelles, Lescarbot, retourné en France en 1607, comme on a vu, et même résidant en Suisse de 1612 à 1614,[85] ne les connaît que par Jean de Poutrincourt qui lui écrit: "Si vous sçaviez toutes les particularités, il y aurait bien de quoy enfler votre histoire."[86] Et sur ce que les lettres de Poutrincourt lui

[83] Il y en a XIX, dans l'édition imprimée, mais, chose curieuse, comme pour le P. Leclercq, il n'y a pas de chapitre XIII.

[84] Livre III, prologue, pp. 203-208: "Ainsy j'ay laissé en entier les deux voyages du dict capitaine Jacques Quartier."

[85] Introduction, édition de 1907-1914, p. XIV.

[86] Edition Grant-Biggar, Toronto, 1907-1914, 3 vols.; vol. III, p. 339, du texte français.

apprennent, il *enfle* son histoire. Lui-même nous l'apprend: "Je relis et avec plaisir entremeslé de regret plusieurs lettres qu'il (Poutrincourt) m'a écrites au sujet de ses voyages, mais particulièrement une confirmative de ce que je viens de dire."[87]

On lit cela justement au chapitre XV qui clôt ce fameux livre V.

Et Poutrincourt lui-même, alors retenu en France, d'où tenait-il ces renseignements? Des rapports de son fils Biencourt, qu'il avait laissé gouverneur de Port Royal. Biencourt était un jeune homme, "un jeune gentilhomme de grande espérance," au dire de Lescarbot. Si Poutrincourt s'est marié en 1590, comme dit M. Sulte,[88] son fils n'avait pas vingt ans en 1611. M. Patterson[89] veut, d'après un document qu'il ne reproduit pas, qu'il soit né en 1583. Mais c'est M. Sulte qui est tombé juste. En effet, dans son introduction[90] au *Factum du procès entre Jean de Poutrincourt et les Pères Biard et Massé,* M. Gabriel Marcel nous dit qu'il a découvert à la Bibliothèque nationale—*Dossiers bleus*—trois pièces relatives à Poutrincourt. La première est précisément "le contrat de mariage de Claude fille de Isaac Pajot, bourgeois de Paris, avec Jean de Biencourt, passé devant Pierre Fardeau au châtelet de Paris le 14 août 1590, lesquels se prennent avec les biens qui peuvent leur appartenir."

Biencourt était donc encore en cet âge où il sied mieux d'être gouverné que gouverneur.

Que les jésuites, qui avaient, grâce aux libéralités de Madame de Guercheville et de la reine, des intérêts dans l'entreprise de Port-Royal, et à qui d'ailleurs leur caractère st leur âge conféraient ce droit, aient donné des conseils à Biencourt, c'est tout à fait probable et c'est dans l'ordre. Que celui-ci, déjà prévenu contre des censeurs jugés importuns, les ait mal reçus, ce n'est pas dans l'ordre, mais c'est bien dans l'humaine nature:

> Un jeune homme toujours bouillant en ses caprices,
> Est toujours . . . .
> Rétif à la censure . . . .

monitoribus asper, comme dit Horace.[91]

De là ces disputes, ces tiraillements qui aboutissent à une rupture complète.

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[87]*Ibid.*, III, 342.

[88]*Mém. Soc. Royale,* 1re série, vol. II, p. 33.

[89]*Ibid.* 11ème série, vol. II, 1896, p. 128.

[90]P. IX, s. note. Dans une addition, à la fin, l'éditeur nous apprend que Biencourt portait les prénoms de Jean-Charles et qu'il ne faut pas faire deux personnages distincts de Jean et Charles.

[91]*Ad Pison.*, v. 163. Boileau, *Art poétique,* liv. III.

Or, sur toutes ces misères, Lescarbot n'accepte qu'une version, celle de Biencourt. Il connaît celle du P. Biard, il la cite mais pour n'en tenir aucun compte. Il est l'intime ami des Poutrincourt, leur admirateur, il a quitté Port-Royal avec regret, il désire de le voir prospérer, et, sur les dires de gens qui ont toute sa confiance. il tient rigueur aux jésuites, qu'ils accusent d'en avoir causé la ruine. Les motifs qui l'ont égaré ne sont pas de ceux qui trouvent place dans les âmes viles: c'est le sentiment patriotique, c'est surtout l'amitié. Mais ces motifs, pour nobles qu'ils soient, nous tenons, avec la plupart de nos historiens, qu'ils ont faussé son jugement généralement si sûr.

Quelle ombre de vraisemblance, par exemple, dans l'accusation que, après la ruine de Saint-Sauveur, le P. Biard ait servi de guide à Argall pour aller saccager Port-Royal? Entre la relation du jésuite et la lettre de Poutrincourt reproduite par Lescarbot,[92] il n'y a pas à hésiter.

Toutefois Lescarbot, même dans ses accusations contre les jésuites, garde un ton digne de l'histoire. Aussi n'admettrons-nous pas sans bonne preuve que l'odieux *factum*, cité plus haut[93] et publié en 1887[94] par M. Gabriel Marcel, soit de sa main,—bien que le P. de Rochemonteix nous dise qu'on l'a soupçonné d'en être l'auteur.[95] Lescarbot l'a connu et même il le cite. Mais cet amas indigeste d'imputations grossières pour ne pas dire ordurières,[96] aux yeux d'un lecteur impartial, ne saurait être de la même plume que *l'Histoire de la Nouvelle-France.* Ce n'est qu'une de ces productions anonymes, un de ces pamphlets violents dont on est si prodigue en France quand on veut à tout prix couler un homme, une cause—ou un ministère—et qui n'ont rien à voir avec l'histoire sérieuse. M. Marcel s'est fait illusion en croyant que cette publication allait 'compléter et modifier dans tous leurs détails les récits de Ferland, Garneau, Harrisse, Sulte," etc.[97]

Ses sentiments, du reste, ont dû légèrement embuer la limpidité de son regard ou de ses lunettes, faire obliquer un tantinet son jugement: "Sans hésitation, nous dit-il,[98] nous ne craignons pas d'attribuer à la haine des jésuites, qui veulent déposséder Poutrincourt, l'échec

[92]Liv. V, ch. XIV, pp. 338, 339: texte fr., édit. citée, vol. III.

[93]P. 13.

[94]80 exemplaires in 4o. Le mien porte le no. 65.

[95]*Op. cit.*, p. 81, note 4.

[96]Ainsi, p. 14, on accuse le P. Biard d'invrognerie en compagnie d'un chirurgien qui avait "mauvais vin et comme on dit, vin de lion; mais quant au P. Biard, ce n'était que vin de pourçeau qui ne demande qu'à dormir ayant rendu gorge."

[97]Introduction, p. XV.

[98]Introd., p. XV.

de notre colonisation en Acadie. . . . Ce n'est pas la première fois et ce ne sera pas la dernière, malheureusement,—M. Marcel prend le ton d'un prophète—que cet ordre néfaste, qui *prend sa consigne hors de France*, aura exercé une influence néfaste—M. Marcel affectionne ce mot—sur nos destinées." C'est nous qui soulignons une des rengaines de ce temps-là. En 1887, manger du jésuite était encore chose bien portée: cela pouvait mener un homme aux plus hautes dignités,—jusqu'au timon de l'Etat. Mais, avec les progrès de la civilisation, cette sorte de cannibalisme en plein Paris, comme l'anthropophagie chez les nègres, tend à disparaître.

S'il était nécessaire de discuter, on peut trouver chez l'adversaire même, dans le fameux *factum*, des arguments sans réplique.

Ainsi à quoi se réduit la ridicule histoire de l'excommunication de Biencourt par les jésuites?[99] Nous en avons là le texte en entier. Or c'est simplement une protestation du P. Biard contre la violence que lui fait le gouverneur. De guerre lasse, son confrère et lui, pour échapper aux tracasseries et à la malveillance, veulent retourner en France sur le vaisseau du capitaine l'Abbé qui va partir, mais Biencourt met arrêt au départ jusqu'à ce que les jésuites aient été déposés à terre, défend au capitaine de les garder à son bord et les somme eux-mêmes de quitter le navire. Quand ils y ont été contraints, il leur ordonne encore de garder leur chambre, défend au capitaine l'Abbé de leur parler sans témoin, même de se charger de leurs missives pour la France. Et toutes ces mesures arbitraires, cette tyrannie intolérable, vous pensez que c'est le P. Biard qui s'en plaint et qui exagère? Non, c'est Biencourt lui-même qui s'en vante. Tout est là dans le *factum*, raconté en deux lettres adressées à Poutrincourt,[100] le 13 et 14 mars 1613,[101] par son fils. Pauvre jeune homme!

Et dire que tout le mal vient de là! que Poutrincourt n'ait pas laissé à la tête de son établissement, au lieu d'un jouvenceau, un homme de sens rassis. C'est contre ces vexations presque incroyables que proteste le P. Biard, non par une excommunication!—c'était un ancien professeur de théologie et il savait à quoi s'en tenir,—mais par un document[102] où il signifie à Biencourt: "1° —Que quiconque me violentera ou me forcera(à) sortir hors (du navire) encourra premièrement l'indignation du Dieu tout-puissant et la sentence d'excommunication majeure."—Le père ne faisait qu'invoquer les pénalités en-

[99]Par le P. du Thet comme dit M. Réveillaud, pour qui père ou frère reviennent au même.

[100]Pp. 48-54.

[101]M. Marcel fait remarquer qu'il faudrait 1612.

[102]Voir le texte *in extenso*, *Factum*, p. 43, ss.

courues, de droit, par ceux qui portent une main violente sur les personnes consacrées à Dieu. C'est *l'immunité ecclésiastique* qui a existé de tout temps et qui existe encore. Il déclare 2°—qu'il ne relève pas de Biencourt, mais du Roy et de son supérieur ecclésiastique; que l'ordre du Roy est qu'on le laisse libre et que personne n'a droit de l'arrêter; 3°—"Que nous ne sommes point subjects de Monsieur de Biencourt, ains ses "associez."

En somme, cette pièce alléguée contre les jésuites est plutôt à leur honneur. Mais laissons! Il y a longtemps que ce procès a été jugé. Que Lescarbot s'y soit laissé tromper, nous le comprenons, nous l'abandonnons sur ce point, mais nous nous gardons bien de le ravaler et de le décrier. Nous lui tenons compte plutôt des récits charmants qu'il nous a transmis sur les débuts de Port-Royal et de l'Acadie.

Le vrai premier établissement de la foi en notre pays, c'est lui et surtout Champlain qui nous l'ont raconté. Car l'Acadie, toute notre histoire en fait foi, c'était une partie de la Nouvelle-France, c'en était une des perles. Or, c'est là que de Monts qui'dans son voyage avec Champlain en 1597, avait été rebuté par les sables, les rochers, l'âpre climat de Tadoussac,[103] voulut en 1604 former un établissement. Mais, au témoignage de Champlain, qui l'accompagnait, Pierre du Gua, sieur de Monts, comme ses prédécesseurs, le marquis de la Roche, le commandeur de Chastes, n'obtenait ces lettres patentes "qu'à condition—tout huguenot qu'il était—de planter (en Canada) la foy catholique, apostolique et romaine—permettant (toutefois) de laisser vivre chacun selon sa religion."[104] C'est pour quoi "il assembla nombre de gentilshommes et toutes sortes d'artisans, soldats et autres, tant d'une que d'autre religions, Prestres et Ministres."[105]

Il n'entre pas dans le cadre de cette étude, déjà trop longue, de raconter les destins des colons de l'île de Ste-Croix et de Port-Royal. Mais, à nous en tenir à l'aurore de la foi en ce pays, il convient d'avouer qu'elle fut assez pâle.

Le texte de Champlain nous met en présence des premiers pretres venus ici au XVII siècle. Quels étaient-ils? combien? et qu'ont-ils fait? On en sait peu de chose. Il y en avait, d'après ce que nous laissent entendre Lescarbot et Champlain, au moins deux avec un ministre calviniste. Un seul est connu, l'abbé Nicolas Aubry[106] "homme

[103] *Voyages de Champlain*, V, 42 (698).

[104] Champlain, *Ibid.*, V, 49 (:705).

[105] *Champlain*, *Ibid.*, p. 50 (706).

[106] Le P. Dagnault, Eud., dans son livre: *Les Français du Sud-Ouest de la Nouvelle-Ecosse*; Valence. 1905, p. 7, le nomme d'Aubrée. Champlain et Lescarbot disent Aubry.

d'Eglise, nous dit Lescarbot, Parisien de bonne famille, à qui il avait pris envie de faire le voyage avec le sieur de Monts, et ce contre le gré de ses parents, lesquels envóyèrent exprès à Honfleur pour le divertir (dissuader) et ramener à Paris."[107]

On ne sait de lui qu'une aventure qui faillit lui coûter la vie. Pendant que les vaisseaux étaient à la baie Ste-Marie, à l'extrémité ouest de l'Acadie, il suivit un groupe de marins dans les bois. En voulant retrouver son épée—il portait l'épée!—qu'il avait oubliée près d'un ruisseau où il avait bu, il se perdit si bien dans la forêt qu'on eut beau sonner de la trompette, même tirer du canon, il fut impossible de le retrouver. On le crut mort. On soupçonna même "certain de la religion réformée, de l'avoir tué pour ce qu'ils se picquoient quelquefois de propos pour le fait de la dicte religion."[108] Ce ne fut que seize jours après qu'une chaloupe étant allée dans ces parages, le pauvre abbé qui mourait de faim, n'ayant pour se nourrir que quelques fruits sauvages, l'aperçut, et, à l'aide d'un mouchoir au bout d'un bâton, put signaler sa présence et se faire repêcher, à la grande joie de tout le monde.

L'abbé Aubry dut retourner en France dès 1605. D'après M. Sulte, il vivait encore à Paris en 1612, désireux de reprendre ses voyages.[109]

Pour son compagnon, il avait souvent, comme l'abbé Aubry lui-même, du reste, maille à partir avec le ministre huguenot et l'on en venait parfois aux arguments violents. Champlain, scandalisé, nous en dit quelque chose: "J'ay vu, dit-il, le ministre et nostre curé s'entrebattre à coups de poings sur le différend de la religion. Je ne sçay pas qui estait le plus vaillant et qui donnait le meilleur coup, mais je sçay très bien que le ministre se plaignoit quelquefois d'avoir esté battu,—et vuidoient de cette façon les points de controverse."[110] Il ajoute cette réflexion pleine de bon sens: "Deux religions contraires ne font jamais un grand fruit parmy les Infidèlles qu'on veut convertir."

Lescarbot nous apprend indirectement que cet abbé batailleur mourut dans l'hiver de 1605-1606, quand il nous dit que Poutrincourt, avant de mettre à la voile, en 1606, "s'informa en quelques églises s'il pourrait trouver un prestre qui eut du sçavoir pour le mener et soulager celui que le sieur de Monts y avait laissé à son voyage, *lequel nous*

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[107]*Op. cit.*, p. 427, s.
[108]Lescarbot, *op. cit.*, p. 428.
[109]*Poutrincourt en Acadie. Mém. Soc. Royale*, 1re série, vol. II, p. 32.
[110]*Voyages*, III, 53: (707).

pensions estre encore vivant."[111] C'est nous qui soulignons.—Ce prêtre était donc mort, vraisemblablement, une des victimes du scorbut qui désola Port-Royal dans l'hiver, comme l'île Ste-Croix l'hiver précédent.[112] Son antagoniste malheureux, le ministre huguenot, eut le même sort, si l'on en croit Sagard—qui, sans être témoin du fait, put l'apprendre de la bouche de Champlain: "En ce commencement, dit le bon frère, que les Français furent à l'Acadie, il arriva qu'un prêtre et un ministre moururent presque en même temps: les matelots qui les enterrèrent, les mirent tous deux dans une même fosse pour veoir si morts ils demeureraient en paix, puisque vivants ils ne s'estoient pu accordér."[113]

Ainsi ni l'abbé Aubry, ni son compagnon n'avaient eu les succès d'un François-Xavier ou d'un François Solano.

En 1606-1607, il n'y eut pas de prêtre à Port-Royal, et ce fut Lescarbot qui, sur la demande de Poutrincourt, consacra son "industrie à enseigner notre petit peuple, pour ne vivre en bestes . . . par chacun dimanche et quelquefois extraordinairement, préque tout le temps que nous y avons esté."[114] Pour un mécréant, ce n'est pas trop mal. A qui voudrait critiquer on pourrait répondre: *Vade et tu fac similiter*—Allez et faites en autant." (Luc, X, 37).

En 1610, un prêtre du diocèse de Langres accompagna Poutrincourt. Il se nommait Jessé Fleché[115] et avait, dit-on, reçu des pouvoirs du nonce Ubaldini.

Comme le fondateur de Port-Royal voulait faire preuve de zèle et mettre en ligne de compte au moins quelques baptêmes d'infidèles, il fit instruire pendant trois semaines, par Biencourt—à qui peut-être quelques leçons de catéchisme n'auraient pas été personnellement inutiles— le grand Sagamo Membertou avec quelques membres de sa famille, et, le 24 juin, 1610, le vieux chef, avec vingt autres sauvages, fut baptisé en grande pompe par l'abbé Fleché. Ces baptèmes au moins prématurés, vantés par Lescarbot, ont été considérés en Sorbonne comme des profanations.[116] Néanmoins, Membertou a gardé la foi et fait, par les soins du P. Biard, une mort chrétienne.

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[111]*Op. cit.*, p. 486.

[112]*Champlain*, III, 41, ss. et III, 80. A Sainte-Croix, il était mort trente six-personnes sur soixante dix-neuf, presque la moitié des colons; à Port-Royal, il en mourut douze sur quarante-cinq.

[113]Hist. du Can., I, p. 26. Ni Champlain ni Lescarbot ne parlent du fait.

[114]*Op. cit.*, p. 463.

[115]Son nom est orthographié de bien des façons. Champlain l'appelle Josué. Mais il importe peu. On le surnommait le *Patriarche*, nom que les Micmacs donnent encore à un prêtre.

[116]Rochemouteix, *op. cit.*, I, 31, note.

Pendant son séjour en Acadie, l'abbé Fleché fit une centaine de baptêmes qu'il eut sans doute le temps de mûrir davantage.

Les jésuites lui succédèrent en 1611 et se mirent à l'oeuvre avec leur zèle coutumier, mais, comme on l'a dit, paralysés par la malveillance à Port-Royal, ils n'y purent faire le progrès qu'ils auraient désiré, et ensuite, en 1613, ils virent ruiner, par le pirate Argall[117] la colonie indépendante de Saint-Sauveur où ils fondaient leurs espérances.

En conclusion, les premiers pionniers de l'Evangile dans la Nouvelle-France, au XVII siècle, furent des prêtres séculiers, puis des jésuites. Les récollets vinrent ensuite.[118]

V

Nous disons au XVII siècle. Ne peut-on pas remonter plus haut, jusqu'à Jacques Cartier?

Discuter à fond ce point demanderait des développements que nous ne nous permettrons pas. On sait qu'au sujet des aumôniers de Cartier, nos historiens, comme les Israelites dans le désert, se sont partagés en quatre camps: camp du silence—de Conrart le silence prudent!—; camp de la négation; camp de l'affirmation, et,—parce que l'un dit oui, l'autre non,—camp du doute. Mais s'il était permis de se réfugier dans le doute, dès qu'un point affirmé par les uns est nié par les autres, quel vaste champ ouvert au scepticisme! Que de vérités historiques, scientifiques et surtout religieuses, mises en cause! Mieux vaut examiner et prendre parti.

Dans le cas présent, parmi ceux qui affirment, on peut compter Ferland,[119] Faillon,[120] le Dr. N.-E. Dionne,[121] M. Sulte[122] qui ne sont pas des plus mal cotés en matière d'histoire du Canada.

Ce dernier, après avoir énuméré les passages de Cartier qui laissent assez entendre que des aumôniers accompagnent le hardi navigateur, conclut nettement: "Voilà assez de preuves pour clore toute discussion."[123]

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[117]Bancroft. Hist. of the U.S. I, 112, qualifie Argall: "A young sea captain of coarse passions and arbitrary temper."

[118]Le R. P. Odoric Jouve, O.F.M., dans son excellent livre: *Les Franciscains et le Canada*, p. 46, s. distingue très loyalement entre l'Acadie et le Canada proprement dit et, en revendiquant pour les récollets le titre de premiers missionnaires du pays, il déclare qu'il entend parler de la rive laurentienne.

[119]*Cours d'Histoire*, I, 22, 170.

[120]*Hist. Col. Fr.*, I, note IX, p. 507, ss.

[121]*Jacques Cartier*, 1889, p. 120, ss. 280, ss.

[122]*Hist. des Can.—Fr.*, I, p. 13.

[123]*Loc. cit.*

Il revient sur ce sujet dans le *Bulletin des Recherches historiques*, en juin, 1914.[124] Il cite les passages assez nombreux du *Brief Récit* et du voyage de 1634 où il est parlé de la messe et conclut: "Va-t-on croire que le mot messe n'avait pas pour les Malouins la même signification que pour nous?—Faut-il penser que, à défaut de prêtres, Cartier lisait ou récitait les prières et croyait bonnement que c'était la messe?"

Nous n'allons pas répéter tous les arguments du débat mais seulement les corroborer par quelques observations qui ont sans doute déjà été faites mais que nous n'avons remarquées nulle part.

1o.—S'il y a une règle de critique historique incontestable,—on peut dire d'inprétation générale,—c'est que les textes doivent être pris dans leur sens naturel, à moins qu'une raison péremptoire n'oblige à les interpréter autrement. Or, ici, pour détourner le mot *messe*, sur lequel M. Sulte a raison d'insister, de sa signification ordinaire, il n'existe pas de raison péremptoire, de *texte contemporain* irréductible. Le seul texte un peu sérieux qu'on puisse alléguer se trouve dans ce passage du *Brief Récit*, où Cartier cherche à se débarasser des importunités des sauvages qui, sans instruction préalable, demandent tous à être baptisés: "Parce-que, dit-il . . . il n'y avait (personne) qui leur remonstrat la foy pour lors, fut prins excuse envers eulx. Et dict à Taignoagny et Domagaya qu'ils leur feissent entendre que retourneryons ung aultre voyage et apporterions des Prestres et du cresme, leur donnant à entendre pour excuse que l'on ne peut baptiser sans le dit cresme."[125]

Et d'abord ce passage n'est pas clair. De plus, il ne nie pas la présence du prêtre. En effet, de ce qu'on dit qu'à un prochain voyage on amènera des prêtres, on ne peut rigoureusement conclure qu'il n'y en avait pas en ce moment,—et d'autant moins, que la raison sur laquelle on insiste, c'est plutôt le défaut de *chrème*, sans lequel on ne peut baptiser. Ce qu'on peut dire de plus, c'est que ce texte *insinue* qu'il n'y avait pas alors de prêtres avec Cartier. Si ce texte était seul, bien qu'obscur, on pourrait lui accorder une certaime force probante. Mais il n'est pas seul! Il y a les textes où il est clairement question de la messe, de la messe *sine addito*—la messe tout court. Dans le second voyage, dont on s'occupe en ce moment, il n'en est question que deux fois: la première, le sept septembre, avant de quitter l'île aux Coudres pour remonter le fleuve: "Le septièsme du dict mois, jour de Nostre-Dame, après avoir ouy la messe, nous

[124]P. 182. A l'occasion, sans doute, d'articles parus dans le *Devoir* de Montréal, le 20, 25, 26, 28 fév. de la même année.

[125]*Brief Récit*, p. 30, éd. Tross.

partimes de la dicte isle;"[126] la seconde, au fort Jacques-Cartier, pendant l'épidémie qui décima les équipages au cours du désastreux hiver de 1635-1636. Et en cette occasion, les choses se font avec solennité. On place "ung ymaige en remembrance de la Vierge Marie contre ung arbre distant de nostre fort d'un trait d'arc," et tous ceux des mariniers qui sont en état de le faire, s'y rendent en procession "chantant les sept pseaumes de David avec la litanie et priant la dicte Vierge qu'il luy pleust prier son cher enfant d'avoir pitié de nous. La messe dicte et célèbrée devant le dict ymaige, se feist le capitaine pélerin de nostre Dame de Roqueamado."[127] Ces textes sont déjà bien clairs—si l'on ne veut pas leur faire violence—mais ils le deviennent encore davantage si on les examine à la lumière du *rolle* des compagnons de Cartier à son deuxième voyage. Ce document a été publié par M. Ramé en 1865,[128] par M. Joüon des Longrais en 1888,[129] reproduit par le Dr. N.-E. Dionne[130] et M. Pope.[131] Un fac-similé s'en trouvait à la bibliothèque du Parlement d'Ottawa et a dû périr dans l'incendie de ce magnifique monument. La bibliothèque de l'Université Laval en possède une copie par l'abbé Laverdière. Il y a des variantes, des différences de lecture, dans ces diverses reproductions, mais ces différences s'expliquent aisément si l'on songe que le document est ancien et ne contient que des noms propres toujours difficiles sinon parfois impossibles à déchiffrer. Or y retrouve les noms de deux personnages ecclisiastique, Dom Antoine et Dom Guillaume Le Breton. Sans être taxé de témérité, ni de conjecture historique, on peut affirmer que les deux textes, le *Brief Récit* et le *rolle* d'équipage, s'authentiquent l'un l'autre, se prêtent une mutuelle clarté. Si d'une part on a la messe, de l'autre on a des prêtres!

Ajoutons un autre texte qui, celui-là, ne permet pas d'épiloguer. Quand Taignoagny et Domagays cherchent à détourner Cartier de son voyage à Hochelaga et lui demandent s'il a parlé à Jésus, il leur répond "que ses prêtres y ont parlé et qu'il ferait beau temps."[132] Or c'est une règle de critique historique[133] qu'un texte obscur, isolé, ne saurait prévaloir contre des textes nombreux et clairs comme ceux

[126] *Brief Récit*, 12 *verso* Ed. Tross. En Bretagne au XVI siècle, la *Nativité* était fêtée le 7 septembre au lieu du 8. Faillon, *op. cit.*, I, 13.

[127] *Brief Récit*, p. 35, *recto et verso.* D'après le manuscrit il faudrait: *la messe dicte et chantée. Ibid.*, p. 61, *verso.*

[128] *Jacques Cartier.* (*Documents inédits sur*), Paris, 1865.

[129] *Jacques Cartier*, documents nouveaux.

[130] *Jacques Cartier*, p. 125, s., le ch. IX, et p. 304.

[131] *Jacques Cartier*, p. 145, s.

[132] *Brief Récit*, p. 19.

[133] V. P. de Smedt, Bollandiste: *Principes de la critique historique* ch. XIII, XIV.

que nous avons rappelés. C'est le texte obscur qui doit être ramené à la teneur du contexte. Et ici la chose est facile. Il n'est pas nécessaire de pressurer, de torturer les mots. Qu'il n'y eût là personne "pour remonstrer la foy aux sauvages" c'est de toute vérité, parce que, pour leur enseigner nos croyances, il fallait savoir leur langue, et, parmi les compagnons de Cartier, personne ne la savait. On n'avait pas Biencourt pour faire le catéchisme![134]

2.—Pour confirmer cette argumentation, qui ne nous paraît pas manquer d'une certaine valeur, une observation, que nous n'avons vue nulle part, aura peut-être quelque poids. Nous voulons parler des *lieux* où, d'après les deux relations du Capitaine Malouin, la *messe* est dite ou célébrée.

On vient de voir que dans le second voyage, il n'est question de la messe que deux fois. Mais dans le premier on en parle quatre fois. Or, où est-ce qu'on "ouyt la messe?"

Après une traversée dont la relation ne dit rien, sauf qu'elle a été heureuse, les vaisseaux arrivent au port de Brest, aujourd'hui l'Anse du Vieux-Fort, dans la baie des Esquimaux, sur la côte du Labrador. C'est là que la messe se dit pour la première fois, le 11 juin et, une seconde fois, le 14, avant le départ.[135] En juillet, on est à Port Daniel, appelé Saint Martin en ce temps là, et là, le 6 juillet, un lundy, s'il vous plaît! toujours avant de partir, on a encore la messe.[136] Enfin le 15 août, à Blanc-Sablon, une autre messe, avant le départ.[137]

Et cela ne signifie rien? Peut-être, quand on est étranger aux règles de la théologie....ou qu'on n'y pense pas....Mais si on les connaît et qu'on y réfléchisse, cela signifie bien quelque chose. Les anciens théologiens, du moins le plus grand nombre, ne jugeaient pas permise la célébration de la messe en mer, et cette doctrine était encore suivie par la Saint Office au XVII siècle.[138] L'on comprend facilement la sagesse d'un pareille sévérité, si l'on songe aux coquilles de noix sur lesquelles les navigateurs couraient alors l'océan. Comment aurait-on pu y célébrer en pleine, sans danger, le saint sacrifice? Mais si l'on rapproche ces règles du fait que pendant les voyages de Cartier, il n'est question de la messe que lorsque l'on est dans un havre,—jamais ailleurs—, on est bien forcé d'admettre—si le parti pris n'est pas trop fort—qu'il s'agit d'une vraie messe, dite par un vrai

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[134]*Suprâ*, p. 22.

[135]*Discours*, etc., pp. 25 et 29. Ed. Tross, 1865.

[136]*Ibid.*, p. 42.

[137]*Ibid.*, p. 67.

[138]Au témoignage de Pignatelli, *apud* Ferraris: *Prompta Bibliotheca*, 1783, Tome V au mot *Missa*.

prêtre et non simplement de l'évangile de S. Jean, comme dit très bien M. Sulte.[139]

3.—Personne, croyons-nous, n'a fait, contre la présence d'aumôniers sur les vaisseaux de Cartier, de plaidoyer plus fort que M. Joseph Pope.

Entr'autres arguments, il insiste sur le silence que garde Cartier au sujet des malades qui semblent laissés sans assistance, sans sacrements, des morts qu'on enfouit sans rites funèbres, sans prières. Et sur ce, il s'exalte, il fait de l'éloquence: "Le chroniqueur se serait fait un devoir de mentionner avec éloge cet héroisme qui distingue toujours le prêtre catholique en pareils cas—inclinons-nous avec gratitude —; il nous aurait décrit l'administration des sacrements et la céromonie solennelle du *Requiem*, etc."[140] Il y en a long et c'est fort touchant..... Mais, non, rien! Une autopsie, des corps enterrés dans la neige,[141] c'est tout.

Mais qu'on veuille bien comparer ce qui se passe ici, au fort Jacques-Cartier, avec ce qui a lieu à l'île Sainte-Croix, trois quarts de siècle plus tard.[142] Ici comme là des malades, des morts, et un grand nombre encore, puisque, sur soixante dix-neuf colons, trente-six succombent à l'île Sainte-Croix, et douze sur quarante-cinq, à Port-Royal (1604-1605-1606) et qu'en dit Champlain? Il note le fait mais parle-t-ils des soins donnés aux mourants, des derniers devoirs rendus aux morts? d'hymnes funèbres et de *Requiem*? Pas un mot, et pourtant il y a des prêtres! On les connaît. Mais pour Champlain, comme pour Cartier, ce qui est de l'ordre ordinaire n'est pas matière à enregistrer. Il y a des malades, on les soigne, on les console; des morts, on les enterre avec les rites imposants de la religion: c'est entendu, c'est la coutume, pas n'est besoin de l'écrire et on ne l'écrit pas.

Quand M. Pope nous affirme que l'auteur des relations de Cartier est fidèle à noter les moindres incidents qui se rattachent à la religion, il fait, pour le besoin de sa thèse, une affirmation pour le moins gratuite. Les faits démontrent le contraire. Ainsi, au second voyage, la flotille part le dix-neuf mai, et quand est-il question d'un office religieux? Le sept septembre, à l'île aux Coudres! L'exemple qu'il cite de la plantation d'une croix à Gaspé, est en tout cas mal choisi. C'était plus un acte civil qu'un acte religieux, une prise de possession au nom du roi de France, et, de droit, le rôle principal de cet acte appartenait

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[139]*Bulletin Recherches* Hist. *loc. cit.*
[140]*Jacques Cartier* trad. de M. Ph. Sylvain des archives fédérales 1890, pp. 64-71.
[141]*Brief Récit*, p. 36.
[142]*Supra*, p. 21, note 8.

au représentant du roi, Jacques-Cartier. Que la croix ait été bénite au préalable, c'est où des aumôniers auraient pu avoir leur place. Mais on n'en dit rien, comme de beaucoup d'autres choses dont on n'a pas voulu charger des récits nécessairement fort courts.

Ajoutons que l'honorable écrivain a eu tort de compter l'abbé Laverdière parmi ceux qui rejettent le fait historique de la présence d'aumôniers dans les voyages de 1534-1535. Dans les notes érudites de son édition de Champlain, le savant abbé parle comme Ferland. Ainsi, au sujet de la messe à la rivière des Prairies, il écrit: "Alors cette messe aurait été la première qui se soit dite au Canada depuis l'époque de Cartier."[143] En plusieurs autres notes il parle de la même manière, laissant assez voir son sentiment.[144]

Par tous ces raisonnements, nous ne prétendons pas convaincre ceux dont "le siège est fait," mais simplement fournir des données aux lecteurs qui ne demandent qu'à être renseignés pour se former une conviction. Pour nous, la présence d'aumôniers dans les équipages de Cartier n'est pas moins indubitable que les voyages mêmes de l'illustre navigateur. Autrement les documents historiques les plus clairs sont à réléguer au nombre des vieilles lunes.

Pour le premier voyage, il n'y a pas de nom connu.[145] Que plusieurs des marins du second voyage aient aussi été du premier, c'est possible, même probable. Mais en histoire, les conjectures—bien qu'à l'ordre du jour—ne comptent pas. A s'en tenir à la liste officielle de l'équipage de 1635,[146] laquelle, en dépit des difficultés paléographiques qu'elle présente, ne saurait être rejetée, les aumôniers étaient Dom Anthoine et Dom Guillaume le Breton. Comme ce titre honorifique *Dom*, simple abréviation de *Monsieur*, réservé aujourd'hui à certains ordres religieux tels que les bénédictins, les chartreux, etc., était porté, en ce temps là, en haute Bretagne, par des prêtres séculiers, même par de simples chapelains,[147] il s'en suit que les premiers prêtres venus en ce pays, non seulement en Acadie, mais sur les bords du Saint-Laurent, les premiers qui y ont célébré la messe, appartenaient au clergé séculier, à l'ordre que le vénérable abbé Olier appelait d'une manière aussi heureuse qu'originale: "l'Ordre de Jésus-Christ."

Ste Foy, 1 mai 1922.

[143]Champlain, Vol. IV, pp. 16, 17 (504-505) note 4.
[144]*Ibid.*, p. 17 (505), note 2.
[145]V. Dionne, *Jacques-Cartier*, ch. IX, p. 113.
[146]*Ibid.*, p. 114.
[147]L. D. Dionne, *op. cit.*, pp. 120, 121, en donne plusieurs exemples.
[148]Faillon, *Vie de M. Olier*, Vol. I, p. 441.

Un probleme de linguistique: les parlers manceaux et le parler franco-canadien

Par l'abbé ARTHUR MAHEUX

Présenté par l'abbé CAMILLE ROY, M.S.R.C.

(Lu à la réunion de mai 1922)

Nous avons pensé qu'il serait intéressant de comparer le franco-canadien, non pas à l'ensemble des dialectes français de l'Ouest, mais à un seul d'entre eux, afin d'atteindre, si c'était possible, à une plus grande précision.

Mais quel dialecte arrêterait notre choix? Nous avons cru préférable de prendre celui dont on trouverait un texte écrit au XVIIème siècle; par hasard, nous avons trouvé un texte manceau publié pour la première fois en 1624; c'est le *Dialogue des trois vignerons du pais du Maine*, par *Jean Sousnor*; des trois interlocuteurs, l'un parle français, l'autre, latin et le troisième s'exprime en patois manceau. Après avoir pris connaissance de ce texte à la Bibliothèque Nationale, nous avons pensé qu'il serait utile de le comparer au franco-canadien; nous voulions déterminer les rapports qui peuvent exister entre le parler du Canada et celui du Maine; des paysans manceaux sont venus au Canada; leur parler a-t-il pu exercer une influence sur le parler canadien? A-t-il en fait exercé une influence? de quelle nature? dans quelles limites? Elucider ces questions devint notre but. Belle ambition! Mais les difficultés n'ont pas manqué. Nous n'avons pas tardé à nous convaincre que le texte patois contenu dans le *Dialogue* était trop court pour servir d'appui à une comparaison sérieuse avec le franco-canadien. De plus, comme le remarque M. Dottin, "il n'est possible de caractériser avec précision les parlers du Bas-Maine qu'en les comparant aux parlers voisins." [1] Il nous fallait donc élargir les bases de notre travail; nous avons étudié le parler moderne du Haut-Maine et du Bas-Maine, en tenant compte à l'occasion, des différences qu'a ce parler avec celui du XVIIème siècle, tel que nous le fait connaître le Dialogue.

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[1] *Cf.* Dottin. Glossaire. Introduction. XLVII.

I

Possibilité de l'influence mancelle

Nous ne saurions nous flatter d'avoir fait connaître, dans cette rapide esquisse, tout le détail des particularités qu'offre le parler franco-canadien; nous avons songé surtout au vocabulaire, sans prétendre présenter des listes complètes, mais seulement des exemples; nous n'avons pas groupé les remarques qu'appellent la phonétique et la morphologie, ce qui nous aurait entrainé trop loin.

Nous avons constaté dans le français du Canada la présence d'un élément dialectal; les exemples que nous avons donnés ne constituent pas une preuve rigoureuse; avant d'examiner quels rapports existent entre le franco-canadien et le manceau, il est utile de donner quelque développement à cette question. Il faut savoir s'il est venu au Canada des paysans du Maine, et à quelle epoque, et dans quelle proportion avec les émigrants des autres provinces de la France: c'est poser la question de l'origine des Canadiens-Français; nous allons essayer de l'expliquer brièvement.

Parmi les historiens du Canada, Charlevoix semble le premier s'être occupé sérieusement de cette question dans son *Histoire de la Nouvelle France*:[2] Margry l'a aussi étudiée dans ses *Origines françaises des pays d'outre-mer*[3] et après lui, Rameau, dans son ouvrage sur *La France aux Colonies*[4] Garneau[5] et Ferland l'ont aussi abordée, ce dernier dans ses *Notes sur les registres de Notre Dame de Québec*[6] et à la fin de la première partie de *son Cours d'Histoire du Canada.* On trouve encore des détails à ce sujet dans *l'Histoire de la Colonie au Canada*[7] par Faillon; Benjamin Sulte y a donné une attention particulière dans son *Histoire des Canadiens-Français*[8] et dans "*La langue française en Canada*[9]; quelques renseignements sont groupés dans un livre de M. E. Dionne: *La Colonie française à la mort de Champlain.* Un travail beaucoup plus considérable a été fait par Mgr. C. Tanguay, qui a publié *le Dictionnaire généalogique des familles canadiennes.*

Ces écrivains ont consulté, soit les Registres de Québec et de Trois-Rivières, sot les actes de mariage de la Colonie, soit les Etudes des Notaires, soit encore les premiers recensements du Canada. Mgr.

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[2]Édition de 1744, vol. III, page 371.

[3]Vol. III, page 652.

[4]Édition 1859, page 282.

[5]Histoire du Canada, 4ème édition, vol. II, page 101.

[6]1863, page 40.

[7]Vol. II, pages 531 et suivantes.

[8]Passim.

[9]1898, pages 9, 10, 11, 33 et 36.

Tanguay a utilisé les documents des Archives du dépôt de la Marine à Paris. Enfin, après avoir consulté ces divers travaux, après avoir compulsé les monographies canadiennes, les registres du district de Québec, la revue "*Canada, Perche et Normandie*" de Gaulier et surtout le Registre de confirmation de Mgr. de Laval, premier Evêque de la Colonie, M. l'Abbé Lortie[10] a repris la question et en a beaucoup avancé la solution; il n'a pas compté "tous les émigrés venus au Canada," mais seulement "ceux dont il a pu découvrir la province d'origine"[11] et il en a trouvé près de cinq mille pour le dix-septième siècle, depuis la fondation de Québec en 1608. Le tableau qu'il a dressé ne permet pas de déduire des conclusions rigoureuses, mais il éclaire grandement une question restée jusque là trop obscure.

Pour la période qui va de 1608 à 1640, on a relevé la province d'origine de près de trois cents émigrants: en voici la liste par ordre numérique:

Provinces	Nombre des émigrants
Normandie	89
Perche	89
Ile-de-France	36
Aunis, Ile de Ré, Ile d'Oléron	23
Beauce	14
Picardie	11
Saintonge	10
Champagne	7
Bretagne[12]	4
Orléanais	4
Anjou	2
Maine	1
Poitou, Touraine, etc.	0

Il est difficile de supposer que la *proportion* qui existe dans ce tableau entre les groupes d'émigrants sera beaucoup changée, si l'on trouve de nouveaux documents. On voit que le groupe normand l'emporte par le nombre pendant cette période de trente-deux ans et on peut croire qu'il a donné le ton du langage populaire.

[10]*Cf.* Bulletin du parler français, vol. I, page 160 et surtout vol. II, page 17, où l'on trouve le tableau rectifié de l'Abbé Lortie.

[11]*Cf.* B.P.F., vol. VIII, page 121, en note.

[12]Nous avons souligné *Bretagne* aussi bien que *Maine* à cause de la ressemblance étroite entre les parlers de la Haute-Bretagne et ceux du Maine. Voir plus loin, page 86.

Le poête Delille, dans son discours préliminaire aux Géorgiques de Virgile,[13] rapporte le fait suivant: " 'Une colonie de Normands, sur la fin du siècle dernier, alla s'établir sur les côtes de Saint-Domingue et forma des flibustiers et des boucaniers. Étant restés vingt ans sans avoir de relations avec les Français, quoiqu'ils communicassent entre eux, la langue qu'ils avaient tous apprise et parlée dès leur enfance se trouva tellement dénaturée, qu'il n'étoit plus guère possible de les entendre."

Il n'en fut pas ainsi des Normands venus au Canada. Les relations avec la France ne furent interrompues que pendant l'occupation anglaise, de 1629 à 1632, et presque chaque année on voyait de nouveaux colons arrivés de France, de la Normandie; c'était un facteur de conservation. D'autre part, on sait que les colons en Canada vivaient en relations constantes avec les représentants de l'autorité civile et ecclésiastique; le premier cultivateur de Québec fut un pharmacien de Paris, Louis Hébert. On peut croire que la conversation presque quotidienne avec ces personnes dont le langage était celui de la Ville ou même de la Cour à Paris, contribua à faire disparaître du langage des paysans les particularités trop accentuées ou du moins à les diminuer.

Dans cette période, le Maine n'est représenté que par un émigrant; son apport fut plus considérable dans la seconde période—(1640-1660):

Provinces	Nombre des émigrants
Normandie	270
Perche	122
Aunis, Ile de Ré, Ile d'Oléron	115
Ile-de-France	76
Maine	66
Anjou	56
Poitou	54
Saintonge	37
Champagne	23
Beauce	22
Touraine	21
Angoumois	13
Bretagne	9
Guyenne	8
Brie	7

[13]Paris. An XI: M.DCCCIII, page 26, en note.

Provinces	Nombre des émigrants
Orléanais	7
Picardie	7
Bourgogne	6
Lorraine	6
Berry	5
Gasgogne	5
Dauphiné	4

En 1660 donc,—si l'on additionne les chiffres donnés dans les deux listes précédentes,—les groupes de colons se présentent dans l'ordre suivant:

Provinces	Nombre des émigrants
Normandie	359
Perche	211
Aunis, Ile de Ré, Ile d'Oléron	138
Ile de France	112
Maine	67
Anjou	58
Poitou	54
Saintonge	47
Beauce	36
Champagne	30
Picard	18
Bretagne	13
Etc., etc.	

L'émigration du Maine est relativement considérable dans cette période, sans doute plus considérable que ne l'indique le chiffre 67, puisque, comme il a été dit, ces listes ne prétendent pas tenir compte de tous les émigrants, et si la Normandie a sa large part, il faut cependant reconnaître que le Maine a pu exercer une certaine influence sur le vocabulaire et sur la prononciation.

De 1660 à 1680, c'est l'apogée de l'émigration:

Provinces	Nombre des émigrants
Normandie	481
Ile de France	378
Poitou	357

Provinces	Nombre des émigrants
Aunis, Ile de Ré, Ile d'Oléron	293
Saintonge	140
Bretagne	108
Champagne	76
Guyenne	61
Anjou	60
Picardie	60
Angoumois	54
Beauce	46
Touraine	42
Bourgogne	36
Orléanais	33
Berry	32
Maine	31
Périgord	28
Languedoc	26
Limousin	26
Brie	25
Perche	24
Gascogne	22

L'Ile de France, le Poitou et quelques provinces du midi fournissent à ce moment un bon nombre de colons; la Normandie, cependant, reste facilement au premier rang, et le Maine ne fournit que 31 de ses enfants.

A la fin de cette troisième période, en 1680, les groupes de colons se placent dans l'ordre suivant:

Provinces	Nombre des émigrants
Normandie	840
Ile de France	490
Aunis, etc.	421
Poitou	411
Perche	235
Saintonge	187
Bretagne	121
Anjou	118
Champagne	106
Maine	98
Picardie	78
Etc.	

La fin du dix-septième siècle (1680-1700) marque le déclin de l'émigration:

Provinces	Nombre des émigrants
Poitou	158
Ile de France	131
Normandie	118
Aunis, etc.	93
Saintonge	87
Guyenne	55
Bretagne	54
Limousin	44
Touraine	28
Angoumois	26
Gasgogne	24
Beauce	23
Champagne	23
Languedoc	23
Anjou	21
Bourgogne	21
Orléanais	19
Picardie	18
Lyonnais	16
Périgord	16
Maine	15
Auvergne	14
Etc., etc.	

A l'aube du dix-huitième siècle, les colons du Canada, si l'on ne tient pas compte de leur descendance, se répartissent comme suit:

Provinces	Nombre des émigrants
Normandie	958
Ile de France	621
Poitou	569
Aunis, Ile de Ré, Ile d'Oléron	524
Saintonge	274
Perche	238
Bretagne	175
Anjou	139
Champagne	129

Provinces	Nombre des émigrants
Guyenne	124
Maine	113
Beauce	105
Picardie	96
Angoumois	93
Touraine	91
Limousin	75
Bourgogne	64
Orléanais	63
Gasgogne	51
Languedoc	50
Berry	42
Périgord	45
Brie	36
Auvergne	35
Lyonnais	33
Dauphiné	24
Provence	22
Lorraine	16
Flandre, Hainaut	15
Artois	14
Savoie	12
Béarn	10
Bourbonnais	8
Nivernais	7
Franche-Comté	6
Marche	6
Comté de Foix	2
Roussillon	2

L'émigration du dix-huitième siècle n'a changé que peu de choses à ces chiffres; Rameau[14] a donné le tableau de l'émigration française au Canada, de 1700 à 1770, c'est à dire, peu après le Traité de Paris qui cèdait le Canada à l'Angleterre; on ne trouve pas un millier d'immigrants. Aussi bien, Garneau a-t-il écrit[15] que le plus grand nombre des émigrés français qui se sont fixés au Canada y sont venus dans le dix-septième siècle et B. Sulte[16] ajoute: "N'oublions pas que,

[14]La France aux Colonies, édition de 1859, p. 282, cité par le Bull. du P.F., vol. I, page 162.

[15]Histoire du Canada, 4ème édition, vol. II, p. 101-102.

[16]B. Sulte. La langue français en Canada, édit. de 1898, p. 12.

en 1673, Louis XIV arrêta l'envoi des colons au Canada, de sorte que les six mille âmes qui s'y trouvaient alors étaient venues dans l'intervalle des quarante dernières années, ou étaient nées sur les bords du Saint-Laurent. . . . Un petit nombre de familles vinrent après 1673. . . ."

Pour ce qui est de la langue, on peut dire que le parler du Canada avait reçu, dès la fin du dix-septième siècle, l'empreinte qu'on lui connait "C'est bien ce que font entendre la Mère Marie de l'Incarnation en 1670, le récollet Chrétien Leclercq en 1680, Bacqueville de la Potherie en 1700, Charlevoix en 1722, et le Suédois Kalm, vers 1748."[17] M. Rivard tire la même conclusion en s'appuyant de préférence sur les remarques de Charlevoix et de Montcalm.[18]

On objectera, sans doute, qu'une centaine de Manceaux n'ont pu exercer une grande influence sur le parler des colons; nous croyons, au contraire, que cette influence a pu s'exercer.

En effet, le nombre des colons venus de France jusqu'à 1680 s'élève seulement à 2542,[19] et nos cent émigrés manceaux en font partie; s'ils ont été disséminés comme une poussière dans les trois régions de Québec, de Trois-Rivières et de Montréal, on conçoit que leur influence ait été presque nulle; mais une telle dissémination n'est pas probable. Ces émigrants ne pouvaient guère se décider à quitter leur pays pour venir au Canada que sur le bien que leur en disaient des parents ou des amis déja installés dans la colonie, et les nouveaux arrivants devaient, en débarquant à Québec, rechercher ceux de leur petite patrie qui les y avaient précédés. Les choses se passent encore ainsi la plupart du temps au Canada et aux Etats Unis. Dans l'Ouest Canadien on voit des villages belges, des villages bretons, des villages allemands, des villages russes. Dans une petite ville, on trouve groupés dans un même quartier les immigrants de même nationalité. Bien plus, dans la province française de Québec, les villes de Montréal et de Québec ont chacune leur colonie française; les immigrants de France forment un groupement un peu à part, qui a ses réunions spéciales. On peut s'imaginer que ce qui se pratique de nos jours dans de grandes villes, dans une province de deux millions d'âmes, dut se pratiquer aussi dans une colonie dont les habitants n'étaient pas trois mille. Les petits groupes reconstituaient, pour ainsi dire, la petite patrie, et, de la sorte, les dialectes ont pu se maintenir dans une certaine mesure: autrement on ne saurait expliquer

[17] *Cf.* A. Lortie, De l'origine des Canadiens-Français, B.P.F., vol. I, page 161, en note.

[18] *Cf.* Rivard. Etudes sur les parlers de France au Canada, page 28.

[19] *Cf.* B.P.F., vol. II, page 18, troisième colonne du tableau.

dans notre langage la présence de trois ou quatre mots pour désigner le même objet: tel de ces mots s'est maintenu dans telle région, tel autre est employé ailleurs. On remarque encore dans les vieilles paroisses de la région de Québec, que les mariages entre parents sont très nombreux, ou que les mariages se font à l'intérieur d'une même paroisse, si bien que l'on a fini par dire que dans telle paroisse tout le monde est parent. On peut donc se figurer que le groupe manceau s'est affermi par ses alliances et qu'il a pu fournir au franco-canadien sa petite part de vocables, de formes, de particularités de prononciation.

D'autre part, il ne faut pas oublier que les dialectes de la Haute-Bretagne ressemblent beaucoup à ceux du Maine, comme le montre M. Dottin dans l'Introduction de son glossaire.[20] Le dialecte bas-breton n'ayant pour ainsi dire exercé aucune influence sur le franco-canadien, il est permis de supposer que le plus grand nombre des émigrants attribués à la "Bretagne" partirent de la Haute-Bretagne; on en comptait près de deux cents à la fin du dix-septième siècle, presque le double des Manceaux. Ces deux groupes ont pu s'appuyer l'un sur l'autre et exercer une influence sérieuse sur la langue en formation au Canada.

Mais, en fait, quelle a été la part d'influence du manceau?

II

Difficultés d'Etablir en Fait l'Influence Mancelle

Le question qui termine le chapitre précédent pose un problème dont nous voulons expliquer les données, les moyens de solution et les difficultès.

Les données du problème.

1°.—Ce que les dialectes ont pu laisser au franco-canadien.

Nous entendons par *dialectes*, "les parlers de la langue d'oil, dont les phénomènes caractéristiques s'accusent dans le nord de la France, dans l'ouest, dans le nord-ouest et le centre. . . . Les parlers en usage dans ces provinces ne peuvent pas être classés rigoureusement . . . mais pour plus de commodité, et à certains faits plus ou moins répandus, on est convenu de distinguer, sans assigner pourtant à chacun d'eux un domaine précis, dans la région du Nord et en s'arrêtant au pays flamand, le picard et la wallon; dans l'est, le champenois, le lorrain, le comtois et le bourguignon; dans le centre, le berrichon, le tourangeau, et, dans le duché de France, le francien ou vieux français; dans l'ouest, en laissant de côté le breton, qui ne nous intéresse pas, le normand, le manceau, le poitevin, l'angevin et le saintongeois."[21]

[20]*Cf.* pages XLIX à LIV.

[21]*Cf.* Rivard. Études . . ., pages 22 et 23.

Ces divers dialectes ont été en lutte les uns avec les autres dans la colonie du Canada. De plus, ils ont eu à lutter contre le français officiel. En effet "un bon nombre des premiers habitants de la Nouvelle France avaient quelque instruction, savaient lire, écrire et compter. Ils l'avaient appris dans les petites écoles de la mère-patrie."[22] La plupart des colons savaient donc entendre et parler le francais. Le peuple, par la situation particulière qui lui était faite au Canada, vivait en relations continuelles avec les officiers de l'Administration, les Membres du Clergé, les missionnaires, les officiers de milice. Dès les premiers temps de la colonie, l'instruction fut abondamment donnée par l'école, le couvent des Ursulines et le Collège des Jésuites où enseignèrent des maîtres français.

De la lutte entre le français et les patois, ces derniers sortirent amoindris, et on peut croire 1° qu'un dialecte n'a eu chance de laisser que ce qu'il de plus caractéristique et que ce que ses sous-dialectes avaient de commun; 2° que les éléments communs à plusieurs dialectes, v.g., au normand, au manceau et au poitevin, ont offert plus de résistance; 3° enfin que, parfois, les éléments faibles de plusieurs dialectes ont pu se fortifier au Canada dans un groupe mêlé.

2°.—La seconde donnée du problème consiste à chercher ce que le dialecte du Maine a fourni au franco-canadien: soit des éléments proprement manceaux dans le vocabulaire, la phonétique, la morphologie et la sémantique ou du moins des éléments que l'on observe très fréquemment dans le Maine et rarement ailleurs; soit des particularités, qui sans s'imposer comme mancelles, ont favorisé le maintien de tel ou tel élément d'un dialecte voisin.

Les moyens de solution

Pour résoudre ce problème, il faudrait d'abord possèder une connaissance exacte du franco-canadien, du manceau actuel et surtout du manceau du dix-septième siècle, ensuite il serait utile de contrôler, dans les registres du Canada et des documents mentionnés ci-dessus,[23] l'indication "*originaire du Maine.*" En outre, il faudrait, autant que possible, déterminer quelles sont les régions et même quels sont les villages d'où sont partis les colons manceaux, chercher si des émigrants portés comme originaires de la Bretagne et du Perche, ne sont pas

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[22] *Ibid.*, p. 17. L'auteur s'appuie sur les preuves données par Mgr. A. Gosselin dans *l'Instruction au Canada sous le régime français* et par J. E. Roy, Histoire de la Seigneurie de Lauzon, vol. I; page 495.

[23] *Cf.* ci-dessus, page 101.

issus des villages de la Haute-Bretagne et du Perche qui sont voisins du Maine et où l'on parle un langage qui offre assez de ressemblance avec celui du Maine. Il serait encore nécessaire de savoir où se sont fixés ces émigrants en Nouvelle France; s'ils ont formé des groupes, si ces groupes ont eu quelque continuité. Enfin, il serait utile de bien connaître les dialectes des pays voisins du Maine. En effet, on peut faire entre les dialectes des rapprochements utiles; c'est ainsi que plusieurs caractéristiques du normand se retrouvent dans le bas-manceau,[24] et que "les parlers français de la Haute-Bretagne . . . paraissent encore plus prochement apparentés aux parlers du bas-Maine que les parlers normands."[25] "Quant aux phénomènes indiqués par Forlich comme caractéristiques du dialecte breton, ou bien ils sont complètement inconnus dans les patois haut-bretons que j'ai recueillis, ou bien ils se retrouvent dans le Bas-Maine."[26]

Les difficultés.

Le seul énoncé des conditions du problème en laisse apercevoir les difficultés.

Il n'est pas possible, à l'heure qu'il est, d'avoir une connaissance exacte du franco-canadien; pour le connaître, il faut recourir, si l'on excepte l'observation personnelle, au lexique publié depuis 1902 dans le Bulletin du Parler Français au Canada. Ce lexique a une valeur réelle; il a été rédigé après une enquête dans tout le Canada Français, enquête dont les résultats ont été contrôlés autant que possible. Pour la comparaison avec le français, le Comité d'Etude a utilisé les meilleurs dictionnaires français: la langue archaique a été étudiée dans le *Dictionnaire des termes du vieux français*, de Borel, le *Glossaire francais* et le *Glossarium mediae et infimae latinitatis* de Du Cange, le *Dictionnaire Français-latin* de Robert Estienne, le *Dictionnaire universel* de Furetière, le *Dictionnaire de l'ancienne langue française et de tous ses dialectes* de Godefroy, le *Dictionnaire historique de l'ancien langage français*, de La Curne de Sainte-Palaye, etc. . . .

La langue populaire a été examinée à l'aide des dictionnaires de Larousse, Guérin, Darmesteter, etc. La langue dialectale de France ne pouvait être étudiée que dans les lexiques et glossaires suivants:[27] Pour la Normandie, Du Bois (1856), et Travers (1856); Delboulle (1876), Robin (1879), Moisy (1887); pour la Picardie, Corblet (1851);

[24] *Cf.* Dottin. Glossaire du Bas-Maine. Introduct., p. XLVIII.
[25] *Cf.* Dottin. Glossaire du Bas-Maine. Introd., p. XLIX.
[26] *Ibid.*
[27] La plupart des études scientifiques faites sur les patois de France n'ont paru qu'après que la Société du Parler français eut commencé ses travaux.

pour la Saintonge, l'Aunis et le Poitou, Favre (1868); Eveillé (1887); pour le Centre, Jaubert (1884); pour la Bourgogne, Mignard (1869) et la Bresse, Guillemault; pour la Haute-Bretagne (Ille-et-Vilaine), Orain (1886); pour le Haut-Maine, Montesson (édition de 1899); le Bas-Maine (Dottin 1899); le Comité a utilisé aussi les revues spéciales et des travaux comme le Glossaire du Parler de Bournois, par Roussey, le Dictionnaire des idiomes méridionaux de Boucoiran (édit. de 1898), etc. . . . et les revues régionales publiées en France. Ces ouvrages ont fait l'objet d'une recherche sérieuse de la part des rédacteurs du Lexique canadien-français; néanmoins, on ne pouvait éviter les erreurs, ni même songer, dans un premier travail, à être complet. Pour notre part, nous avons revu chaque mot du Lexique canadien-français et nous avons cherché dans le Glossaire du Bas-Maine, de Dottin, si le terme canadien n'avait pas son semblable dans le bas-manceau; nous avons trouvé près de cent trente rapprochements intéressants qui ne se rencontraient pas dans le Lexique; ils feront sans doute partie de la première édition du Lexique, que prépare la Société du Parler français au Canada; mais le travail publié depuis 1902 dans le Bulletin du Parler français demeure incomplet sur plus d'un point et constitue pour le moment un outil imparfait pour l'étude que nous avons entreprise.

Sera-t-il facile au moins d'avoir une meilleure connaissance du parler manceau? Si l'on s'en tient au parler actuel, il faut distinguer entre le Haut-Maine et le Bas-Maine.

Le Vocabulaire du Haut-Maine, du comte de Montesson, parut vers la moitié du siècle dernier,[28] à une époque où, selon M. Dottin,[29] "on était préoccupé du sens et de l'étymologie plutôt que de la prononciation, et où jamais on n'aurait songé à recueillir pour chaque mot les moindres variantes de sons. Tout au plus, dans les Préfaces, les auteurs accordent-ils quelques pages ou quelques lignes à la prononciation locale. Les préoccupations orthographiques, singulièrement déplacées lorsqu'il s'agit de dialectes parlés et non écrits, empêchaient de noter exactement les mots. On écrivait les mots, tantôt d'après la prononciation, tantôt d'après l'analogie superficielle ou réelle des mots français qui semblaient apparentés aux mots patois, et il n'était pas rare qu'une cacographie ne déguisât à tout jamais le terme en question. D'excellents Glossaires, comme le Glossaire du Centre de la France de Jaubert, et le Vocabulaire du Haut-Maine de R. de Montesson, ne sont pas exempts de ce défaut."

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[28]La seconde édition est de 1859.

[29]Dottin. Glossaire du Bas-Maine. Introd., p. VIII.

La troisième édition du Vocabulaire du Haut-Maine, parue en 1899, n'a pas changé la qualité des deux premières éditions. Dans son *avis au lecteur*, le comte Charles Raoul de Montesson écrit: "Fallait-il modifier la forme primitive de l'ouvrage? lui enlever son cachet littéraire et provincial? le présenter sous l'habit scientifique de la philologie française moderne? Le conseil m'en a été donné. Mais un simple compilateur ne pouvait aborder cette tâche; le temps passait. . . . Pour ces deux raisons et d'autres encore, le *Vocabulaire* est resté ce qu'il était: format, disposition, simplicité, ce sont les mêmes errements."[30]

Il en va tout autrement du Glossaire du Bas-Maine, de M. Dottin. Cet ouvrage se présente avec des garanties scientifiques. Cependant il faut entendre l'auteur exposer les difficultés de son entreprise. "Le travail qui m'était proposé présentait quelques difficultés. Il est relativement facile de composer le glossaire d'une personne ou même d'un village. Dans le parler d'une personne, en effet, un mot donné n'a en général qu'une forme; dans le parler d'un village, un mot n'a guère qu'un petit nombre de formes différentes. . . . Mais si l'on prend pour objet d'études une province même peu étendue, comme le Bas-Maine, il est presque impossible d'atteindre à une précision vraiment scientifique.

"Si l'on est justement préoccupé de noter exactement les nuances des sons, on ne trouvera point de mot qui ne possède une multitude de variantes selon les villages où il est en usage. Si l'on tient à préciser la signification de chaque mot, il faudra tenir compte des variations nombreuses de sens qui existent souvent d'une commune à l'autre. Enfin, si l'on veut déterminer l'extension géographique de chaque terme, il faudra faire une enquête portant sur tous les mots et tous les lieux du Bas-Maine."[31]

S'il est déjà si difficile de connaître le parler actuel du Maine, comment pourra-t-on étudier le manceau du dix-septième siècle que parlaient les colons du Maine venus au Canada? Les textes écrits en manceau ancien ne sont pas nombreux. Il y a d'abord les Chartes; elles sont du treizième, du quatorzième et du quinzième siècles. La plupart, quarante-deux, ont été étudiées par Görlich;[32] quatre autres ont été publiées par Bellée.[33]

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[30]*Cf.* Montesson. Vocabulaire. . . . Avis au lecteur, pages VI et VII.

[31]*Cf.* Dottin. Glossaire. Préface. Pages VI et VII.

[32]Görlich—Die nordwestlichen Dialecte der Langue d'Oil. Heilbronn. 1886, dans le tome V des Französischen Studien de Kärting et Koschwitz.

[33]Bellée. Du dialecte manceau (Congrès archéologique de France au Mans et à Laval, 1878).

Ensuite, on trouve au dix-septième siècle le Dialogue des trois vignerons du pays du Maine. . . par Jean Sousnor, dont la première édition est de 1624.

Comme la plupart des Chartes, le Dialogue appartient au parler du Haut-Maine. Malheureusement, on ne peut pas tirer de cet ouvrage tout le profit désirable. La notation des sons n'y est pas uniforme: nos s'écrit *nos* ou *naux*; on y trouve *crere* à côté de *croire*, *vilein* non loin de *vilen*, parfois une seule et même combinaison de lettres représente des sons différents: *en* représente nasal dans: *pen* (pain), *ben* (bien) et a nasal dans: *l'en* (l'on), *men* (mon); la séparation des mots est défectueuse; il y a beaucoup de fautes d'impression; l'auteur a modifié sur certains points l'orthographe traditionnelle;[34] enfin, le texte reste court et incomplet; le livre est petit. Il n'a que 133 pages dans la première édition, et des trois interlocuteurs, un seul parle le patois manceau. Nous avons donc de ce côté une difficulté sérieuse; il y en a une troisième: en effet, nous avons donné le chiffre des émigrants manceaux d'après le tableau publié par M. l'abbé Lortie, où ils sont portés comme originaires du *Maine*. Il y aurait lieu de savoir le sens précis de ce mot au dix-septième siècle, soit dans la bouche des émigrants eux-mêmes, soit dans la pensée de ceux qui ont rédigé les documents cités plus haut;[35] il conviendrait encore de savoir de quels villages sont venus nos colons manceaux. En poussant ces investigations, nous pourrions peut-être résoudre la quatrième difficulté qui consiste à savoir quel a été le nombre des émigrants venus de la Haute-Bretagne et du Perche avoisinants le Maine et dont le parler peut être apparenté de près au patois manceau.

Le cinquième moyen de connaître l'influence mancelle sur le franco-canadien consiste à déterminer de quelle façon les émigrants du Maine se sont fixés au Canada et si leurs groupes ont eu quelque stabilité. Nous ne croyons pas que ces recherches aient été faites jusqu'ici, mais nous les croyons possibles, en utilisant les documents qui ont servi à l'abbé Lortie, spécialement le Dictionnaire généalogique de Mgr. Tanguay, les tableaux généalogiques—déjà publiés—des familles de la Rivière-Ouelle, de la Beauce, de l'Ile d'Orléans, et quelques monographies de familles canadiennes. Nous espérons aborder un jour ces recherches.

Enfin, une dernière difficulté vient de la connaissance imparfaite que nous avons des dialectes parlés dans les pays qui touchent au Maine de près ou de loin: Normandie, Haute-Bretagne, Touraine,

[34]Pour ces critiques, nous renvoyons à l'étude de ce dialogue faite par M. Dottin dans la Revue de Philologie française et de littérature tome 12, 1898, pages 278-280.

[35]*Cf.* ci-dessus, p. 101.

Orléanais, Beauce, Ile-de-France, Poitou, Saintonge, Picardie, Champagne, etc. . . .

Or la plupart des lexiques et glossaires de ces provinces[36] méritent les mêmes critiques que M. Dottin a faites de l'ouvrage de Montesson et de celui de Jaubert.[37] A l'époque où ils ont été publiés, la question de l'étymologie paraissait la plus importante; on la néglige aujourd'hui avec raison, à cause de ses nombreuses difficultés. Par contre, on ne donnait pas alors assez de place à la prononciation des mots, à ses variantes et à sa notation exacte; on ne s'occupait pas de délimiter géographiquement l'usage de chaque mot D'autre part, ces ouvrages n'ont pas toujours eu soin de distinguer dans le parler d'une province les divers éléments: archaique, populaire, dialectal qui s'y trouvent; la question de l'emprunt aux dialectes voisins et à la langue littéraire n'y est pas abordée. Dottin fait observer "que même de nos jours, la syntaxe des parlers populaires a été à peine étudiée et que dans les monographies dialectales que nous possédons, la syntaxe occupe une place insignifiante."[38] Enfin, ces sortes de livres n'ont pas été faits, semble-t-il, avec l'intérêt qu'ils méritaient: parmi leurs auteurs, les uns n'ont songé qu'à faire "un catalogue nécrologique en commémoration des mots trépassés;"[39] les autres ont eu des patois une assez médiocre estime, témoin ces paroles de l'Iintroduction au Glossaire du Poitou, de la Saintonge et de l'Aunis, par Favre:[40] "Le Glossaire que nous publions pourrait faire supposer que nous voyons avec regret disparaître le patois. Qu'on nous permette de déclarer que nous n'avons aucun désir de le tirer de la tombe où il dort depuis quelques années. Nous l'étudions avec ce sentiment qui nous fait dessiner les ruines d'un chateau féodal, avant que la dernière pierre ne soit emportée pour la construction d'une maison d'école ou d'un presbytère."

Il est facile de voir que le problème n'est que posé; il n'est pas résolu; mais, comme nous le disions dans l'introduction, il semble que la question valait la peine d'être posée. Nous laissons aux lecteurs le soin de dire si nous nous sommes trompé.

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[36]Nous avons énuméré ci-dessus ceux que la Société du Parler français a consultés: voir page 117.

[37]*Cf.* plus haut, page 118. Voir aussi Dottin. Introd., p. XLVII.

[38]*Cf.* Revue de Philologie française et de Littérature, vol. 12, 1898, p. 282.

[39]Paroles citées par C. H. de Montesson, dans l'avis au lecteur mis en tête du Vocabulaire du Haut-Maine, page VII, édition de 1899.

[40]Page LXXX.

La Morale et la Sociologie

Par l'abbé ARTHUR ROBERT

Présenté par l'abbé CAMILLE ROY, M.S.R.C.

(Lu à la réunion de mai 1922)

Dans son dernier livre,[1] M. Georges Valois parle de gens "mus par la volonté de créer l'ordre," mais égarés par des conceptions absurdes de l'ordre. On peut en dire autant de certains sociologues contemporains. Soucieux eux aussi de "créer l'ordre" dans le monde où ils vivent, ils ont malheureusement de la science sociale un concept faux dont l'application conduirait à l'instabilité et à la ruine.

Parmi eux tiennent le premier rang MM. Emile Durkheim et Lévy-Brühl professeurs à la Sorbonne. Ils estiment tous deux[2] que la science sociale doit s'inspirer d'un esprit nouveau pour devenir *sociologie scientifique*, c'est-à-dire, *vraie science des moeurs*. Pour cela il lui faut rompre en visière avec la Morale qui a fait faillite sur toute la ligne. Inutile de tenter à nouveau de renouer les liens qui les unissaient dans le passé. C'est de cette union mal assortie que vient tout le mal dont nous souffrons. Aussi déclarent-ils qu'entre la Morale et la Sociologie il y a conflit inévitable. Et, tout naturellement, dans ce conflit, la Morale aura le dessous. Sa suppression s'impose, car sur ses ruines la Sociologie a l'ambition d'édifier une science nouvelle sur laquelle on fondera un *art moral rationnel* qui remplacera avantageusement les théories traditionnelles.

. . . .

Sous la rubrique de *théories traditionnelles*, prennent place tous les systèmes: morale kantienne, morale utilitaire, morales empiriques et intuitives, morales déductives et inductives. Tout ce que, au cours des âges, les philosphes moralistes ont enseigné, passe au crible de leur critique. Rien n'échappe à leurs investigations. Et, disons-le tout de suite, de cette course un peu hâtive à travers les doctrines morales, ils reviennent fermement convaincus que celles-ci prétendent à des titres auxquels elles n'ont aucun droit.

En effet, la Morale tout court, de quelque nom qu'elle s'affuble, commence par se proclamer "science normative." Rien d'étonnant

[1]D'un siècle à l'autre, Nouvelle Librairie Nationale, 7. 50.

[2]L. Lévy-Brühl, *La morale et la science des moeurs*. E. Durkheim, *De la division du travail social.*

que les philosophes lui ait consenti cette dénomination sans récriminer. Au fait, l'éthique n'est-elle pas une théorie et une application? Elle formule des principes et elle trace des règles pratiques de conduite. Cette définition, on l'avait unanimement admise jusqu'en ces dernières années. Et voilà que maintenant, aux dires des deux champions autorisés de la sociologie contemporaine, il n'en est plus ainsi . . . "Science normative," selon eux, est un concept contradictoire. Cela est évident, puisque la science comme telle est la connaissance de ce *qui est* et non de ce qui *doit être.* Elle est en plus une investigation désintéressée dont le but est de *rechercher* les lois des phénomènes et non de les *juger.* Or toutes les morales sont par essence *législatrices,* elles *prescrivent* les fins auxquelles les hommes doivent tendre. Elles sont donc *normatives* de leur nature, elles sont *pratiques.* C'est dire qu'elles ne peuvent revendiquer le caractère *théorique* ou *scientifique.* Mais prescrire ce qui *doit être,* dirons-nous, suppose la connaissance de ce *qui est.* En d'autres mots, pratique et théorie sont deux termes qui se supposent et qui se postulent. Les deux vont bien ensemble, ou mieux, doivent aller ensemble. Alors le concept de "science normative" confine nullement à la contradiction. Sans doute, répondent-ils, pratique suppose théorie, mais ils ajoutent que la théorie n'est pas le résultat des propres recherches de la morale. Dans ce cas, d'où lui vient-elle? Elle lui est fournie, disent-ils, par la métaphysique et les sciences positives. Et ainsi la morale ne serait théorie, ne serait science que *de nom,* que *par emprunt.*[3]

La morale vise encore à une sorte d'infaillibilité. Si l'on en croit les moralistes, les préceptes qu'ils imposent ou qu'ils recommandent découlent toujours des théories qu'ils énoncent. Entre les deux, il y a lien nécessaire. Et cette déduction rigoureuse assure la stabilité à la conduite, elle est une garantie contre l'erreur.

Vaine prétention, s'écrie M. Lévy-Brhül. L'expérience confirme que la déduction entre les règles pratiques et les principes de la Morale est purement apparente. Une comparaison attentive entre les différents systèmes de morale à la même époque et dans la même civilisation nous convainc facilement que, en général, ils aboutissent à des préceptes *semblables.* Et pourtant les théories morales sont bien distinctes, pour ne pas dire opposées.

Avec plus de pénétration, M. Durkheim, de son côté, passe en revue la plupart des systèmes de moralité. Et il conclut que les formules qu'ils ont proposées successivement sont fautives. Aussi il affirme l'absence de tout lien logique entre elles et les obligations

[3]E. Durkheim, *Les règles de la méthode sociologique.* S. Deploige, *Le conflit de la morale et de la sociologie.*

individuelles ou sociales qui paraissent en découler. Affirmation osée de prime abord, tout de même fondée, si l'on accepte sa preuve. A son avis, ces formules morales sont creuses et manquent d'empirisme. Créées de toute pièce, elles représentent un idéal qui convient à l'homme abstrait, et dont la réalisation obligatoire serait la suprême rêgle de conduite. Après tout, les maximes morales s'adressent à des individus, à des êtres concrets, et non à des abstractions. Et alors, il parait plus que difficile de les rattacher à ces conceptions métempiriques inventées par des philosophes en mal de légiférer, et pour qui la différence des doctrines vient uniquement de ce que l'être humain n'est pas partout conçu de la même manière.

C'est là un vice de méthode assez sérieux. Et avec ces bâtisseurs de systèmes plus férus l'idéologie que de réalité, nous sommes loin d'être en possession de la stabilité promise et à l'abri de toute erreur.

Enfin on reproche à la Morale de s'appuyer sur des postulats inadmissibles.

Une de ses grandes illusions est de croire la nature humaine, individuelle et sociale, toujours identique à elle-même dans tous les siècles et dans tous les pays; et, logiquement, elle pense de même de la conscience,—c'est le deuxième postulat,—dont le contenu formerait un ensemble harmonique, un tout homogène.

Il y a là grave défaut de perspective. Les théoriciens de la morale, ils ne se sont pas aperçus qu'ils affirment du tout ce qui convient à la partie seulement. Car cette nature humaine qu'ils connaissent, fût-ce même au triple point de vue psychologique, moral et social, n'est qu'une portion de l'humanité. C'est le type d'une race, d'une époque. C'est le Grec pour la philosophie ancienne, c'est le citoyen de la cité chrétienne et occidentale pour les philosophes modernes. Et puis la science comparée des civilisations et des institutions, l'ethnographie, nous montrent l'humanité subissant des hausses et des baisses et offrant ici et là un aspect toujours nouveau. Quant à la conscience, son contenu est d'une composition plutôt hétérogène, puisque les pratiques et les prescriptions qui la lient sont d'une provenance et d'un âge extrêmement différents. Les unes sont de date récente, les autres remontent très haut dans l'histoire; celles-ci viennent de la coutume, celles-là ont été imposées par des législateurs. Elles portent donc toutes en elles-mêmes les traces de la plus évidente disparité, et la seule unité dont elles jouissent est celle de la conscience vivante qui les contient, laquelle évolue comme le milieu qui l'entoure.[4]

[4]E. Durkheim, *La science positive de la sociologie en Allemagne. Introduction à la sociologie de la famille.*

Tels sont les principaux griefs de la Sociologie contre la Morale. Comme on le voit, ils sont l'exécution en règle d'une discipline qui de temps immémorial occupe presque la première place dans la hiérarchie des sciences.

Par manière d'oraison funèbre, il est vrai, on veut bien lui reconnaître quelques états de service. Alors qu'on la déclare en banqueroute, on lui donne des coups d'encensoir. Ainsi, il est tout juste d'admettre qu'elle a éveillé une certaine curiosité intellectuelle d'où est sorti le besoin de se rendre compte des règles pratiques. Et, sans elle, probablement ne serait pas née la vraie science des phénomènes moraux, c'est-a-dire la sociologie scientifique. Hommages trop discrets et trop peu compromettants pour infirmer en quoi que ce soit les accusations sérieuses dont on la croit coupable.

Au fond, les moralistes sont surtout blâmés d'avoir voulu déduire leurs prescriptions de leurs théories. Entre les deux, il n'y a pas de pont. . . . Et cette prétendue légitimation des préceptes de conduite est pur jeu de dialectique, car les règles de morale ne doivent pas leur autorité aux doctrines inventées pour les soutenir. Ils se croient fondateurs. Or les morales ne se fondent pas. Elles existent indépendamment de toute spéculation. N'est-il pas vrai qu'il y a certaines manières d'agir qui apparaissent comme obligatoires, d'autres comme défendues, d'autres enfin comme indifférentes? Ce sont des *données*. Et donc, construire ou déduire logiquement la morale est une entreprise vaine et hors de propos.

D'ores et déjà, la réalité morale doit être l'objet d'une recherche désintéressée et théorique. En y réfléchissant, l'homme n'aura d'autre but que l'acquisition du savoir. Il lui est interdit de s'enquérir désormais de ce qui *doit être*. Le temps de prescrire est passé. L'époque scientifique, l'époque de progrès où nous sommes arrivés réclame une étude positive des faits moraux qui somme toute sont des faits sociaux. Ceux qui s'adonnent aux sciences sociales doivent de plus en plus suivre l'exemple des physiciens. Ces derniers, on le sait, étudient la nature sans aucune préoccupation utilitaire. Que les expériences tentées conduisent parfois, même souvent, à des résultats inattendus, déconcertants, devant lesquels s'évanouissent des théories, des opinions chères à plus d'un titre, ils en font le sacrifice généreusement. Pourvu que la science progresse, c'est tout ce qu'ils demandent.

Bel exemple proposé aux moralistes. Qu'ils renoncent bravement à la vielle manie de légiférer. Se rendre compte de ce *qui est*, pour en *découvrir* les lois et non pas les *constituer*, voilà leur programme de demain. "Et à l'ancienne spéculation dialectique sur les concepts se substituera la recherche scientifique des lois de la réalité.

"Plus tard enfin le savoir théorique prêtera à des applications. Un art rationnel, moral ou social, se fondera, qui mettra à profit les découvertes de la science. Il emploiera à l'amélioration des moeurs et des institutions existantes la connaissance des lois sociologiques." [5]

. . . .

Mais quelle est au juste cette Sociologie qu'on oppose à la Morale? Les griefs que ses représentants les plus en vue ne cessent de faire aux moralistes nous ont déjà appris qu'elle se vante d'être purement théorique c'est-à-dire scientifique. Son idéal est de marcher sur les traces des sciences naturelles, lesquelles se cantonnent dans la réalité objective sans souci aucun de ce qui peut en résulter. Elle est donc, la Sociologie de MM. Durkheim et Lévy-Brühl, une sorte de *physique sociale* soumise au déterminisme que, du reste, toute science requiert.

Et cette nouvelle science des moeurs, parce que en conflit avec toutes les théories morales, est une discipline véritable à part, ayant une méthode et un objet qui sont bien *siens.*

Depuis Platon, pense M. Durkheim, c'est la "conception artificialiste" de la société qui a prévalu. Toute la philosophie morale se ramenait à un *art politique,* à un ensemble de règles s'adressant aux différents groupes sociaux non pas tels *qu'ils étaient,* mais bien tels qu'on *les faisait.* Et si pénétrantes, si judicieuses que soient les observations d'Aristote, de Bossuet, de Montesquieu et de Condorcet sur la vie des sociétés, elles n'échappent cependant pas à cette manière factice d'observer les phénomènes sociaux. A ces grands génies, comme à tous les autres, la connaissance du principe fondamental, base de la sociologie scientifique, a fait défaut.

Ce qui importe avant tout, pour devenir vrai sociologue, c'est de commencer par se débarrasser de ces notions toutes faites, simplement artificielles, nullement représentatives de la réalité concrète. Et une fois ce maquis embrousaillé mis au rancart, il faut poser ce principe que "les sociétés sont des êtres naturels, des organismes se développant en vertu d'une nécessité interne."[6]

Voilà un principe que battent en brèche et historiens et philosophes. Aussi doutent-ils de la possibilité d'une science proprement dite de la société. "Nous avons étudié les sociétés, disent les premiers, et nous n'y avons pas découvert la moindre loi. L'histoire n'est qu'une suite d'accidents, locaux et individuels, qui ne se répètent jamais, réfractaires à toute généralisation, c'est-à-dire à toute étude scientifique, —puisqu'il n'y a pas de science du particulier."

[5]Simon Deploige, *ouv. cit.*, p. 18.
[6]Simon Deploige, *Ibid.*, p. 21.

Si vraiment il n'y a pas de lois, par le fait même l'immuable se trouve exclu. Il ne reste plus qu'un amas plus ou moins confus de faits disparates sans aucune liaison entre eux. Et leur connaissance n'est jamais capable de constituer une discipline réellement scientifique.

M. Durkheim ne contredit pas. Et comme il espère, dans un avenir assez prochain, découvrir les lois sociologiques auxquelles doit infailliblement conduire l'étude positive des phénomènes, en attendant il demande qu'on fasse crédit aux sociologues. Il trouve que la similitude constatée entre les faits attribués à des individus semblables dans des milieux analogues est suffisante pour justifier la marche en avant. "Si différents, dit-il, qu'ils puissent être les uns des autres, les phénomènes produits par les actions et les réactions qui s'établissent entre des individus semblables placés dans des milieux analogues, doivent nécessairement se ressembler par quelque endroit et se prêter à d'utiles comparaisons."

Ici les philosophes entrent en scène. "La liberté humaine, objectent-ils, exclut toute idée de loi et rend impossible toute prévision scientifique."

M. Durkheim répond en disant que "la question de savoir si l'homme est libre ou non a sa place en métaphysique; les sciences positives peuvent et doivent s'en désintéresser." Cependant, pour sauvegarder le caractère de nécessité, sans quoi la science même positive est impossible, il a recours au principe de causalité, encore que ce principe, il lui reconnaîsse seulement une valeur empirique. Et quant à la question de savoir si toute contingence en est exclue, il ose affirmer que le débat n'est pas encore tranché. "La sociologie, écrit-il, n'a pas plus à affirmer la liberté que le déterminisme. Tout ce qu'elle demande qu'on lui accorde, c'est que le principe de causalité s'applique aux phénomènes sociaux. Encore ce principe est-il posé par elle, non comme une nécessité rationnelle, mais seulement comme un postulat empirique, produit d'une induction légitime. Puisque la loi de causalité a été vérifiée dans les autres règnes de la nature; que progressivement elle a étendu son empire du monde physico-chimique au monde biologique, de celui-ci au monde psychologique, on est en droit d'admettre qu'elle est également vraie du monde social. Mais la question de savoir si la nature du lien causal exclut toute contingence n'est pas tranchée pour cela."

Il est facile de s'apercevoir que cette nouvelle science des moeurs, cette sociologie dite scientifique est le contre-pied exact de la vieille morale sociale. Celle-ci a pour dogme fondamental le dualisme, c'est-à-dire la séparation totale de l'humanité du reste du monde.

Les faits sociaux sont des phénomènes particuliers régis par des lois particulières soustraites au déterminisme aveugle constaté dans l'autre partie de l'univers. Il y a donc distinction, voire opposition, entre ces faits et ceux de l'ordre physique.

La sociologie contemporaine fait la guerre à cette doctrine. Elle prêche l'unité, à cette condition seulement l'avenir de la science est assurée. Et la véritable science de la société n'est possible que si elle devient positive. Pour cela, il faut, coûte que coûte, que les phénomènes qui ressortissent à l'humanité soient traités comme les phénomènes naturels soumis à des lois nécessaires.

Appliquer la même méthode à des objets diamétralement opposès, cela parait paradoxal pour le moins. Nous verrons plus loin pourquoi ce procédé n'est pas admissible. Disons, en attendant, que c'est dans cette assimilation contre nature que gît la cause principale du prétendu conflit entre la Morale et la Sociologie.

L'unité de nature, voilà qui rend possible la sociologie scientifique. Tout de même, cela ne suffit pas pour la constituer science indépendante. Elle doit avoir en plus un objet qui ne soit qu'à elle, qui soit vraiment *sien*.

Cet objet, c'est la société elle-même. "Il ne peut y avoir de sociologie, dit M. Durkheim, s'il n'existe pas de sociétés, s'il n'y a que des individus." Et pour lui, "la société n'est pas une simple collection d'individus, mais un être qui a sa vie, sa conscience, ses intérêts, son histoire. Sans cette idée, il n'y a pas de science sociale."

On ne saurait le nier, si les individus n'existaient pas, les sociétés ne seraient que de pures possibilités. Le tout ne se conçoit pas sans les parties. Cependant, les deux diffèrent, au point, parfois, d'avoir des caractères opposés. Les hommes forment la société. Celle-ci est un être tout à fait nouveau, un être social à part, qui a sa nature et ses lois propres. Mais d'où viennent ces phénomènes nouveaux dont il est impossible de retrouver même le germe dans aucun des éléments? Ils viennent de l'association. C'est cette dernière qui est vraiment la cause de l'apparition des propriétés inconnues jusque là. Chose étrange . . . pourtant, les individus sont bien les parties constitutives du grand tout appelé société. Comment expliquer qu'on ne les retrouve plus comme tels? "Je ne nie pas du tout, écrit M. Durkheim, que les natures individuelles soient les composantes du fait social. Il s'agit de savoir si, en se composant pour donner naissance au fait social, elles ne se transforment pas par le fait même de leur combinaison. La synthèse est-elle purement mécanique ou chimique? Toute la question est là."

Ça ne fait pas de doute, pour M. Durkheim, la synthèse est chimique. "Il existe vraiment un règne social, aussi distinct du règne psychique que que celui-ci l'est du règne biologique et ce dernier, à son tour, du règne minéral." [7]

Si la société est un être différent du tout au tout des individus qui la composent, elle a aussi une conscience distincte de celles des particuliers. C'est la conscience collective qui a ses lois propres. C'est une individualité psychique d'un genre nouveau qui a ses manières à elle de penser et de sentir.

La séparation entre le règne social et le règne psychique ne veut donc pas dire que l'élément mental est éliminé de la sociologie scientifique. Et de fait nous trouvons l'expression d' "âme collective" sous la plume de ses représentants. Tout de même, cela ne prouve pas qu'ils ont de cette âme comme de la conscience collective une notion juste. Car, selon eux, la conscience tant individuelle que sociale, est seulement "un ensemble plus ou moins systématisé de phénomènes *sui generis*."

Dans la nouvelle science des moeurs il n'est pas question des individus. Ceux-ci ne comptent pas, c'est le groupement qui est tout. Aussi bien la méthode de la sociologie scientifique ne peut être psychologique. Jusqu'ici, les économistes, tout en admettant qu'il y a des lois sociales nécessaires comme les lois physiques, croyaient tout de même que dans la société seul l'individu est réel. Et, pour eux, les lois sociales ne sont pas des faits généraux induits de l'observation des différents groupements, mais bien les conséquences logiques de la définition de leurs parties. Dans ces conditions les lois sociologiques ne seraient que les corrollaires des lois plus générales de la psychologie.

Au dire de M. Durkheim, cette méthode dénature les phénomènes sociaux. Car un groupe ne pense pas et n'agit pas comme les particuliers. Les membres isolés ont des caractères qu'on ne retrouve pas dans l'ensemble. C'est donc mal interpréter un fait social que de le comparer à un fait particulier. Il faut ériger en principe qu'un fait social ne peut être expliqué que par un autre fait social.

Il y a encore danger à vouloir transporter la méthode biologique dans le domaine social. Sans doute, Auguste Comte appelle la société un organisme. Mais il ne faut pas oublier qu'il ne voyait dans cette expression qu'une métaphore. Au reste, entre le règne social et le règne biologique, les différences sont très marquées. Et les analogies dûment constatées de ces deux sciences ne permettent pas de confondre leurs procédés. Ce qui revient à dire que la méthode

[7]S. Deploige, *ouv. cit.*, p. 26.

pour étudier les phénomènes sociaux est indépendante de toute autre méthode scientifique, elle doit être strictement sociologique.

En résumé: "Au delà de l'idéologie des psycho-sociologues, comme au delà du naturalisme matérialiste de la socio-anthropologie, il y a place pour un naturalisme sociologique qui voit dans les phénomènes sociaux des faits spécifiques et qui entreprend d'en rendre compte en respectant leur spécificité. La sociologie n'est l'annexe d'aucune autre science; elle est elle-même une science distincte et autonome." [8]

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En entendant les sociologues contemporains se récrier avec une si belle assurance contre ce qu'ils appellent la "morale théorique des philosophes," on est porté à croire vraiment qu'il ne reste plus rien de l'éthique dont vécurent les générations des siècles passés. Et aussi en présence des termes nouveaux qu'ils emploient et des griefs nombreux et étranges qu'ils formulent, vient tout naturellement à l'esprit la pensée que le conflit entre la Morale et la Sociologie est né d'hier. Il y a là une double méprise qu'il importe de dissiper. Disons-le tout de suite, les coups de la sociologie scientifique n'atteignent pas la *vieille morale*, la morale traditionnelle, dont le représentant le plus autorisé est saint Thomas d'Aquin. Car les systèmes qu'elle critique sont loin de résumer tous les efforts de l'esprit humain depuis qu'il spécule sur les problèmes moraux et sociaux. Et la lutte que l'on fait avec raison à la morale incriminée ne date pas d'aujourd'hui. Longtemps avant MM. Durkheim et Lévy-Brühl, il y eut de vrais sociologues qui eux aussi ont fait des reproches mérités à de prétendus philosophes trop partisans de la déduction à outrance. Nous assistons seulement à une reprise des hostilités.

Les problèmes qui intéressaient les anciens moralistes, nos sociologues actuels ne s'en occupent pas. "Libre à la métamorale, ecrit Lévy-Brühl, de s'attacher aux problèmes de la destinée de l'homme, du souverain bien, etc., et de continuer à y appliquer sa méthode traditionnelle." C'est à la méthode suivie dans le passé qu'ils en veulent. Rompre avec elle et en adopter une nouvelle, voilà leur but. "La question soulevée, ajoute, Lévy-Brühl, ne porte que sur l'objet et la méthode d'une science."

Quelle est donc cette méthode que la sociologie condamne?

Nous la connaissons déjà. Rappelons-le brièvement, cette méthode est celle de ces moralistes qui construisent de toutes pièces une soidisant science normative, en partant de la définition abstraite de

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[8]S. Deploige, *ouv. cit.*, p. 29.

la nature humaine. Et comme celle-ci, considérée au strict point de vue métaphysique, est identique à elle-même et dans les individus et dans les sociétés, ils prescrivent des règles de vie et des principes d'organisation géométriquement déduits d'un idéal proposé à tous comme un axiome, et jouissant de l'universalité dans le temps et l'espace.

Cette conception fantaisiste de la science morale n'est pas celle que se faisait saint Thomas d'Aquin au treizième siècle. Elle est venue au monde beaucoup plus tard. Et c'est Jean-Jacques Rousseau qui en est réellement le père. Le grand Docteur admet l'existence d'une morale individuelle et d'une morale sociale. L'une et l'autre ont un objet distinct, et donc, l'une et l'autre forment une science différente. La morale sociale se subdivise en morale domestique et en morale politique selon qu'elle s'occupe de la famille ou de l'Etat.[9] Cette division tripartite, les philosophes moralistes critiqués par l'Ecole sociologique la négligent, car, pour eux, "la société n'est qu'une collection et la fin d'une collection ne peut avoir sa raison d'être que dans celles des éléments qui la composent." Aussi dérivent-ils de la nature de l'individu les préceptes de la vie collective et font-ils de la science sociale une simple déduction de la science morale.[10]

Ce manque d'empirisme, d'objectivité, reproché à bon droit à la "morale théorique des philosophes," la philosophie sociale de saint Thomas d'Aquin n'a rien à y voir. S'il y a une morale objective c'est bien celle du Docteur Angélique. Elle est l'expression adéquate de la réalité. L'observation sérieuse, intelligente, désintéressée des phénomènes d'ordre individuel et social a amené ce grand philosophe à admettre l'existence d'une double loi, dont l'une régit les individus, l'autre, la famille et l'Etat. Ces deux lois dont la découverte est le résultat d'une induction scrupuleusement conduite s'imposent d'une manière évidente à l'esprit. Elles sont comme deux postulats, deux axiomes qui servent de base à toute la science sociologique. Et tout naturallement ces lois font naître des préceptes qui commandent, qui défendent ou qui laissent libre. Il y a en effet des actes qui sont obligatoires, d'autres qui sont défendus, d'autres enfin qui sont indifférents.

Cette manière de faire de la science sociale échappe sans doute aux critiques des sociologues contemporains, lesquels, comme nous l'avons vu, reprochent aux philosophes de vouloir *fonder* la morale. Eux aussi, à la suite de saint Thomas, admettent des *données*, in-

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[9]S. Thomas, In decem libros ethicorum, lib. I, Lect. I. Sum. Theolo. II a II ae, Q. 47, art. II. Q. 48, art. 7 ad 2.

[10]S. Deploige, *ouv. cit.*, p. 278.

démontrables, évidentes, qu'ils appellent "morale spontanée." Quel que soit le nom, la chose est la même.

Et quoi qu'en disent nos modernes, on sait depuis longtemps que les phénomènes sociaux ne sont pas abandonnés à l'arbitraire et au caprice. Semblables sous quelques rapports aux faits du monde physique, les actes individuels et collectifs résultent avec une régularité plus ou moins ponctuelle, de causes discernables. Il est donc inexact de mettre cette découverte au crédit d'Auguste Comte. Certainement le fondateur du positivisme affirme que les phénomènes sociaux sont assujettis à de véritables lois naturelles, et partant, sont aussi susceptibles de prévision scientifique que tous les autres phénomènes quelconques, mais bien longtemps avant lui saint Thomas, par son exemple, a démontré la possibilité d'une discipline destinée à découvrir, au moyen de la méthode inductive, les lois des faits moraux et sociaux [11]

Cette discipline, pour le grand docteur, a les caractères des sciences pratiques.[12] Elle est d'abord une science, parce qu'elle nous donne la connaissance du réel. Elle nous dit le pourquoi des habitudes, des lois, des institutions. Pratique ensuite, parce qu'elle est ordonnée à l'action. Elle répond plus spécialement au besoin d'agir, alors que la science spéculative répond surtout au besoin de savoir. Or MM. Durkleim et Lévy-Brühl voient en cela une flagrante contradiction. Selon eux la dénomination de science pratique, de "science normative" est contradictoire dans les termes. La science,—ils ne cessent de le répéter,—de sa nature est plutôt théorique, elle a pour fonction de connaître ce *qui est.* L'Ethique, au contraire, prescrit ce qui *doit être.* C'est le côté pratique, normatif. Ces deux expressions, science et normative, s'excluent donc. Et c'est pourquoi l'Ethique ou la Morale ne peut être une science.

Etrange façon de raisonner, c'est le moins qu'on puisse dire. Ils ne s'aperçoivent pas qu'en réalité cette science pratique de saint Thomas équivaut à leur nouvelle science des moeurs et à l'art moral qu'ils cherchent. Au fond c'est une question de mots. Somme toute, ils sont d'accord presque avec la philosophie thomiste. Et c'est l'ignorance de celle-ci qui les a conduits à condamner en bloc toutes les théories morales qui ont été en vogue autrefois.

Ils réclament, ces Messieurs, l'étude positive des faits sociaux afin d'arriver à la découverte de leur lois. Nous l'avons vu, c'est la méthode qu'a suivie le Docteur angélique. Tout de même ils soutiennent que cette étude est tout à fait désintéressée. Ils se gardent bien, à les entendre, de toute intention d'ordre pratique ou utilitaire. Ce

[11]S. Deploige, *ouv. cit.*, 287-288.

[12]S. Thomas, *Ethicorum*, II. 12. *Politicorum*, *Prol.*

ne sont là que des protestations verbales. C'est une "tactique," c'est une manière de faire admettre la nécessité de rompre avec les errements du passé. . . . Chez eux comme chez saint Thomas, il y a des préoccupations pratiques. N'est-pas Auguste Comte qui enseigne que la sociologie doit fournir à l'art politique l'indication de moyens d'action efficaces et sûrs?[13] Et M. Durkheim lui-même, malgré son dessein de "faire la science de la morale," se défend bien de ne se proposer aucun but pratique. "Mais, dit-il, de ce que nous nous proposions avant tout d'étudier la réalité, il ne s'ensuit pas que nous renoncions à l'améliorer; si nous séparons les problèmes théoriques des problèmes pratiques, c'est pour nous mettre en état de mieux résoudre ces derniers."[14] Quant à M. Lévy-Brühl, il ne craint pas de déclarer que le but de la sociologie scientifique est double: fonder une science de la nature morale et un art rationnel qui tire des applications de cette science. N'est-ce pas sans s'en douter, revenir pas par des chemins apparemment différents à la conception thomiste? Leur science sociale comme celle des aristotéliciens passe de la théorie à la pratique. Après s'être enquis le mieux possible de l'état de la société, les vieux moralistes lui prescrivaient ensuite des règles. Pour eux, la pratique était le prolongement de la théorie. Malgré les apparences contraires, les sociologues contemporains pensent de même. La nouvelle science des moeurs,—leurs écrits en font foi,—est la base d'un édifice dont la politique leur apparait le faîte. L'une est le prolongement de l'autre. Les deux forment un tout.

Il est donc permis de conclure avec M. Deploige que "leur science des moeurs+leur art rationnel=la *scientia practica* de saint Thomas."

Et lorsqu'ils disent que la morale est tout au plus science *de nom, par emprunt*, c'est encore une façon de parler que leur impose leur manie de tout réformer. Assurément la morale dépend de la métaphysique, des sciences positives. Elle s'appuie sur des données qu'elle n'a pas pour mission de démontrer, données que lui fournissent la métaphysique et l'observation. Mais de ces principes elle déduit des conclusions, et c'est en cela que consiste le propre de la science. Du reste, toutes les sciences en sont là, toutes elles supposent des postulats, des axiomes qui leur viennent d'une discipline supérieure. Celle-ci, c'est la métaphysique. Et affirmer que la morale est une science d'emprunt, veut dire qu'elle dépend d'une autre qui est sa directrice. Mais cet état d'infériorité ne lui enlève pas le caractère de la vraie science. Et il est faux de croire qu'elle n'en a que le nom.

[13]Cours de philosophie positive, 48 leçon, t. IV, p. 408.

[14]*La science des moeurs et la morale*, pp. 9, 33.

Encore à leur insu, nos sociologues contemporains semblent d'accord avec la vieille morale. Cette dernière, ils le concèdent, est subordonnée à la métaphysique et à l'expérience Sa partie théorique, elle l'emprunte à la reine des sciences. Les pratiques qu'elle impose, elle les appuie aussi sur la métaphysique. Il y a donc entre les deux véritable lien logique, véritable déduction, fondée sur la réalité, et non simple jeu d'esprit, dialectique pure.

Ce n'est un secret pour personne, la sociologie scientifique veut être en marge de toute métaphysique et surtout de la métaphysique scolastique. Elle n'a réussi que peu ou prou. M. Durkheim est métaphysicien à sa manière quand il tente de définir, de délimiter l'objet de la nouvelle science des moeurs. Cet objet est la société mais une société nouveau genre, diamétralement opposée aux éléments qui la constituent. L'association des éléments entre eux pour former le tout, il la compare à une synthèse chimique. Et voilà donc un groupement où on ne trouve rien des parties qui le composent. Etrange conception de la collectivité qui fut malicieusement soulignée par G. Tarde. Celui-ci, qui est loin d'être un partisan de la scolastique, n'a pu s'empêcher d'exprimer sa surprise[15] "M. Durkheim, dit-il, s'appuie sur un postulat énorme pour justifier sa chimérique conception; ce postulat c'est que le simple rapport de plusieurs êtres peut devenir lui-même un être nouveau, souvent supérieur aux autres. Il est curieux de voir des esprits qui se piquent d'être avant tout positifs, méthodiques, qui pourchassent partout l'ombre même du mysticisme, s'attacher à une si fantastique notion." Et ailleurs,[16] il ajoute: "M. Durkheim nous rejette en pleine scolastique."

A l'école de la scolastique M. Durkheim eut appris que la société n'est pas un être individuel comme le composé chimique ou le corps vivant, qu'elle n'est pas non plus une chose distincte de ses associés, mais qu'elle est bel et bien eux-mêmes. A fréquenter saint Thomas, il se serait convaincu qu'entre les membres de la société il y a influence mutuelle, incessante, entr'aide, coordination d'action et coopération d'efforts. Ce qui exclut la fusion des unités en une seule et sauvegarde le véritable caractère du tout social, lequel "est un état de choses et non une chose; un mode d'être et non un être."[17] Il aurait certainement tiré grand profit à méditer les lignes suivantes du grand Docteur: "L'unité, formée par ce tout qu'on appelle l'Etat ou la famille, est une unité de coordination et non une unité simple. Chaque élément du tout social a son activité qui n'est pas celle de l'ensemble; mais le

[15]La sociologie élémentaire, p. 223.
[16]La logique sociale, p. VIII.
[17]S. Deploige, *ouv. cit.*, p. 193.

tout lui-même a aussi, comme tel, une action qui lui est propre. Par là, la société diffère du tout dans lequel on trouve l'unité de composition, ou de liaison, ou de continuité; ici les parties n'agissent pas séparément de l'ensemble. Aussi n'appartient-il pas à la même science d'étudier le tout social et ses éléments, et les lois qui régissent la vie individuelle, la vie familiale et la vie politique relèvant de trois disciplines differentes."[18]

Si la société absorbe l'individu, celui-ci n'existe plus. D'où la négation de la morale individuelle et la théorie chère à M. Durkheim, à savoir que tout ce qui est obligatoire est d'origine sociale et que les faits moraux sont des faits sociaux.

Il ne faut pas encore trop se fier à ces affirmations catégoriques. Elles suintent la polémique, ce qui leur fait perdre de la valeur. D'ailleurs, elles sont contredites par d'autres trouvées dans les écrits de M. Durkheim. Voici une réponse faite par lui à M. Fouillée qui l'interrogeait sur ce sujet: "Nous ne soutenons pas qu'il n'existe absolument rien de moral ou d'immoral qui ne soit d'origine sociale. Une affirmation aussi catégorique et à priori n'aurait rien de scientifique." Sans doute à un autre endroit, il dit tout le contraire: "Quant à ce que l'on appelle la morale individuelle, si l'on entend par là un ensemble de devoirs dont l'individu serait à la fois le sujet et l'objet, c'est une conception abstraite qui ne correspond à rien dans la réalité. L'homme n'est un être moral que parce qu'il vit en société; faites évanouir toute vie sociale, et la vie morale s'évanouit du même coup, n'ayant plus d'objet où se prendre."[19]

Cependant il s'oublie jusqu'à soutenir des thèses de morale individuelle. Ainsi il enseigne que "les passions doivent être limitées."[20] C'est l'intérêt et le bonheur de l'individu qui l'exigent. Pour le même motif "le suicide doit être classé au nombre des actes immoraux."[21] Et lorsqu'il répète encore que "la morale ne peut avoir pour objectif que la société et non la perfection de l'individu,"[22] il se heurte toujours à ce fait indéniable, à savoir l'existence des devoirs individuels. Mais nullement embarrassé, il répond comme suit: "je ne me suis jamais occupé de principes de l'action individuelle."[23]

Monsieur Durkheim est donc plus moraliste qu'il ne le croit. Il ne peut, quoi qu'il fasse et quoi qu'il dise, ne pas s'occuper "des

[18] *Année sociologique*, t. X, p. 360.

[19] *De la division du travail social.*

[20] *Le suicide*, p. 272.

[21] *Ibid.*

[22] *Determination du fait moral*, p. 115.

[23] A. Comte, *Plan des travaux scientifiques nécessaires pour réorganiser la société.*

principes de l'action individuelle." La morale, de par sa nature même s'étend aux individus d'abord et à la société ensuite. Et c'est tellement vrai que, comme nous venons de le constater pour M. Durkheim,—et nous pourrions en dire autant de tous les autres,—nos sociologues contemporains, même les plus férus de science positive et les plus opposés aux vieux systèmes, acceptent sans trop le savoir cette double division.

C'est dire à nouveau que la morale thomiste se trouve en bonne posture. Et le conflit dont on parle avec une certaine complaisance, n'existe donc pas réellement entre elle et la sociologie scientifique.

Mais alors les griefs de MM. Durkheim et Lévy-Brühl n'ont pas leur raison d'être? Oui, ils sont justifiés en tant qu'ils atteignent ces philosophes qui, selon le mot de M. Durkheim, "construisent la morale de toutes pièces pour l'imposer ensuite aux choses." Or ces philosophes, ce sont surtout Jean-Jacques Rousseau et les spiritualistes cousiniens. C'est de leurs doctrines, qu'il appelait la "politique métaphysique," que Comte faisait déjà le procès en 1822. Entre autres choses, il leur reprochait de revendiquer les droits de la "physique sociale," de faire prédominer l'imagination sur l'observation, de faire régner l'absolu dans la théorie et l'arbitraire dans la pratique.[24] Et n'allons pas croire, tout de même, comme c'est l'habitude, que Auguste Comte est le premier à dire aux moralistes de si grosses vérités. Longtemps avant lui, Saint-Simon avait tenu à peu près le même langage.[25] Et un quart de siècle plus tôt, de Maistre a fait la critique de la politique métaphysique et posé les principes essentiels de la Sociologie contemporaine. Dès 1796, celui-ci dénonce les erreurs des théoriciens de la Révolution française, lesquels ont rédigé des constitutions pour "l'homme," entité imaginaire, abstraite.[26] Le conflit entre la "morale théorique des philosophes" et la sociologie n'est donc pas né d'aujourd'hui. Nous ne faisons qu'assister à une reprise des hostilités. Et il est aussi inexact de considérer Auguste Comte comme le fondateur de cette nouvelle science des moeurs qu'il appelle la Sociologie. Le mot, nous le concédons volontiers, il en est l'inventeur, mais la chose, il la doit en partie à ses devanciers. Du reste, Comte lui-même avoue avoir subi l'influence de Joseph de Maistre. Et l'on peut ajouter que Saint-Simon l'a mis sur la voie.

. . . .

Il ne faudrait certes pas exagérer les points de ressemblance entre la sociologie contemporaine dite scientifique et la morale thomiste. Le parallèle établi entre ces deux disciplines ne regarde que la méthode,

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[25]*Mémoire sur la science de l'homme.*

[26]Considérations sur la France.

et nous avons vu comment la vieille morale échappe aux critiques en partie justifiées des sociologues modernes. Encore une fois ces derniers n'en veulent qu'à cette conception fantaisite, abstraite, du droit naturel imaginée par Rousseau et ses adeptes. Mais leur tort a été d'ignorer totalement la philosophie morale d'Aristote complétée par Saint-Thomas. Leurs attaques ont eu cependant un excellent résultat. Elles ont prouvé une fois de plus que la doctrine sociale du Docteur Angélique réalisait la plupart des conditions que réclame une sociologie vraiment positive.

Nous disons la plupart des conditions, car, il est important de le rappeler, il y en a quelques unes que le thomisme ne saurait admettre. Ainsi, sous le prétexte d'ètre très objectif, M. Durkheim souhaite que les phénomènes moraux et sociaux soient traités comme les phénomènes naturels qui sont soumis à des lois nécessaires. C'est l'abolition du dualisme, c'est-à-dire de la séparation entre l'homme et le reste de l'univers. C'est pourquoi il appelle la nouvelle science des moeurs *Physique sociale.* Cela laisse entendre que la méthode de la sociologie scientifique doit être celle des sciences naturelles.

Nous avons dans ce procédé un vice de méthode qui saute aux yeux. Sans doute M. Durkheim admet un "règne social, aussi distinct du règne psychique que celui-ci l'est du règne biologique et que ce dernier, à son tour, l'est du règne minéral," sans doute encore il ne veut pas transporter la méthode biologique dans le domaine social, mais en pratique sa méthode vraiment sociologique est celle des sciences physiques et naturelles puisqu'elle est basée sur la suppression du dualisme, de la distinction entre les phénomènes moraux et ceux du monde physique. C'est donc du déterminisme pur et simple et la négation de toute liberté. Saint-Thomas, au contraire, s'appuie sur le dualisme voulu par la nature des choses et traite les faits du monde moral et social selon les lois qui leur sont propres. On aura beau dire, c'est certainement plus objectif, et partant, plus scientifique. Car vouloir introduire dans le domaine de la sociologie la nécessité inéluctable qui régit l'histoire naturelle, c'est s'exposer aux pires mécomptes et aux conséquences les plus désastreuses.

Cette méthode est certainement plus qu'empirique, elle ne recourt pas à l'observation comme à un précieux auxiliaire, quitte ensuite à faire appel à la déduction; non, pour elle, l'expérience est tout. On explique pourquoi chez nos sociologues modernes le principe de casualité sans être absolument nié est interprété d'une façon qui n'est pas du tout la véritable. Pour la scolastique, il y a un lien entre la cause et l'effet, qui est la causalité. Celle-ci, elle n'est pas l'objet de l'Obervation, de l'expérience sensible, mais seulement de la raison pure.

Elle est quelque chose de nécessaire, d'immuable. Or, nous l'avons dit plus haut, M. Durkheim pense que n'est pas encore tranchée "la question de savoir si la nature du lien causal exclut toute contingence." Cela nous montre le caractère nettement positiviste de la nouvelle sociologie. Aussi ses partisans se vantent-ils de ne pas s'occuper du problème de la finalité. Ici encore nous serions tentés de dire qu'il ne faut pas se fier à leurs affirmations, car à les lire on est enclin à les prendre pour des déterministes en théorie et des finalistes en pratique.[27] Mais n'empêche qu'ils ont réellement "la phobie des fins." Et c'est toujours sans le savoir ou mieux sans le vouloir qu'ils arrivent à des conclusions semblables à celles du thomisme.

Maintenant si nous envisagions la sociologie scientifique au point de vue de la solution des problèmes qui intéressent l'humanité, nous verrions combien elle est inférieure à l'Ethique aristotélicienne et thomiste. Mais passons. Comme MM. Durkheim et Lévy-Brühl ramènent tout le conflit à une question de méthode, c'est sur ce terrain que nous avons voulu rester. Et les griefs sérieux, fondés la plupart du temps, faits à la "morale théorique des philosophes" ne s'adressent pas à la morale sociale de Saint-Thomas. La morale thomiste, elle, a toutes les conditions pour être vraiment sociologique. C'est dire que la sociologie n'est pas seulement une science positive, mais aussi normative. C'est une philosophie de l'action, elle doit tracer une ligne de conduite. Aussi bien entre elle et la morale il n'y a pas de conflit. L'une et l'autre se prêtent main forte, ou mieux la sociologie est une partie de la Morale Sociale.

Et alors, quoi qu'en pensent certains auteurs,[28] il y a une sociologie catholique comme il y a une sociologie socialiste. Ce n'est pas le lieu ici de démontrer la supériorité de celle-là sur celle-ci.

Disons, pour conclure, que les vrais principes sociaux, on les trouve dans les enseignements de l'Eglise catholique, laquelle est la gardienne non seulement de la morale surnaturelle mais même du droit naturel, c'est-à-dire du juste et de l'honnête, car la morale naturelle prescrit des choses conformes à la droite raison. Or, écrit Léon XIII,[29] "on ne saurait donner le nom de droite raison à celle qui est en désaccord avec la vérité et la raison divine; ni plus appeler bien véritable celui qui est en contradiction avec la bien suprême et immuable, et qui détourne et éloigne de Dieu les volontés humaines."

Et un philosophe catholique contemporain, de haute envergure, M. Jacques Maritain, confirme à sa manière l'assertion du grand pape.

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[27]S. Deploige, *ouv. cit.*, p. 293.

[28]Pierre Méline, *Le travail sociologique.*

[29]Encycl. *Sapientiae Christianac.*

Nous citons: "L'Eglise de l'Ordre! disait Charles Mauras en 1906, en parlant de l'Eglise romaine, dans les admirables pages qui servent d'introduction au *Dilemme de Marc Sangnier.* C'est dans l'Eglise seule, héraut de l'ordre surnaturel et sauvegarde de l'ordre naturel, que l'ordre apparait en plénitude, dans sa splendeur et sa pureté métaphysiques. Partout ailleurs parmi nous il est diminué et étriqué, réduit à notre humaine nature.[30]

Non l'ordre divin ne détruit pas l'ordre purement humain, "il le perfectionne, et sans nul détriment pour la justice il répand sur lui les divines influences de la bonté."[31]

C'est la grande vérité qu'il importe de prêcher à notre époque si désemparée.

L'équilibre social ne sera rétabli que lorsque l'on aura compris la nécessité de la subordination de l'humain au divin, du matériel au spirituel.

Mais pour cela on doit donner la première place à l'Eglise catholique, qui est la véritable pacificatrice des peuples.

[30]*Revue des jeunes*, 25 fevriér 1922, pp. 453-454.
[31]*Ibid.*

Poèmes[1]

Par ALPHONSE DÉSILETS

Présenté par l'honorable C.-F. DELÂGE, M.S.R.C.

(Lu à la réunion de mai 1922)

LE LABOUREUR A DIT

La semaine est finie et la semence est faite;
Demain nous chômerons puisque c'est jour de fête.

Seigneur, daignez jeter un oeil sur nos travaux:
Voici le laboureur, l'araire et les chevaux.

Sur le sol ameubli par le soc et la herse
Le blé fut répandu comme s'épand l'averse.

Nous n'avons épargné ni le grain ni l'engrais.
Et pour que les oiseaux qui nous suivaient de près

Aient eu leur part aussi, nous avons, sur la pierre,
Laissé couler un peu du sac en bandoulière . . . .

Afin que le grenier regorge de moisson
Et que du blé doré naisse le pain de son;

Afin que le cellier abonde et que la huche
Ne s'ombrage jamais des trésors de la ruche;

Afin que chaque année, au pied du crucifix,
Mon épouse vaillante apporte un nouveau fils.

Soyez béni, Seigneur, dans la terre féconde
Dont la vertu nourrit et conserve le monde!

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[1]Extrait d'un ouvrage en préparation: "Dans la brise laurentienne."

Lis et Feuilles D'Erable

Vous incarnez, pour nous, l'aieule vénérée,
Celle qui nous a pris, jadis, sur ses genoux,
Qui nous a fait notre âme et notre coeur à nous,
La France inoubliable et la France adorée.

Vous avez son sourire et son verbe touchants
Et c'est sa gaîté claire, en vous, qui nous appelle.
Nous la reconnaissons, elle est candide et belle,
La France des "trouveurs" qui renaît par vos chants. . . .

Chantez, pour qu'au foyer canadien nul n'oublie
L'harmonieux élan de l'amour filial,
Et pour que se conserve au drapeau lilial
Le culte originel par où le sang nous lie.

Chantez! Que vos accents éveillent désormais
L'enthousiasme saint et le respect du verbe.
Que l'âme canadienne, héroique et superbe,
Prolonge ici la France et n'abdique jamais.

Et pour la faire aimer d'une amitié durable,
Autour de leurs grands bers, aux marmots qui viendront,
Nos petites mamans, en chantant, marieront
A votre fleur de lys notre feuille d'érable. . . .

Le Feu Sous la Cendre

A mon père

On s'attache au passé. Lorsque j'aurai vieilli
Et que je reviendrai, par les soirs de dimanche,
Vers les champs où mon coeur de terrien tressaillit
Une joie auréolera ma tête blanche.

Fidèle au souvenir des jours laborieux,
Où j'ai peiné conformément au dur précepte,
Je reverrai surgir de terre, sous nos yeux,
La forêt primitive et dont l'ombre intercepte
La lumière joyeuse et douce du matin.
Et notre humble maison, le berceau de ma race,
Telle que je la vis en un rêve lointain,
Me réapparaîtra faraude dans sa grâce.

Mes aieux partiront à l'aube, ayant au bras
La hache et le fusil, et le rire à la bouche;
Et, tandis que choiront l'orme et le frêne gras,
Soudain déguerpira l'ours agile et farouche.
Et, de l'aube au coucher, les sonores échos
Révèleront la tâche ardente et formidable. . . .

Or, à la fin, par un de ces matins pascaux
Je verrai l'un des miens, vieux et méconnaissable,
Se coucher à son tour comme un arbre géant.
L'un de ses fils prendra le sceptre du domaine
Et sous l'avril nouveau, drus et réjouissants,
Les blés comme autrefois jailliront de la plaine.
De génération en génération,
Dieu bénira la paix du laboureur austère
Et la prospérité sera dans sa maison.

Mais, un jour que l'épreuve, aux vivants salutaire,
Dispersera les coeurs et les bras généreux
La maison quittera sa joie accoutumée.
Et la douce maison, dans l'attente de ceux
Qu'elle a chéris, longtemps demeurera fermée.

La vertu du foyer pourtant vivra toujours.
Car, sous la cendre inerte, une ardente étincelle
Ranimera soudain le feu des anciens jours
Et la maison rassemblera ses fils en elle.
Les aïeux revivront dans notre souvenir
Et nous rappellerons leurs vertus à la plèbe.
Car, loin d'abandonner jamais de les bénir,
Je veux que nous gardions à ces faiseurs de glèbe,
Dont l'effort a semé la paix sur nos chemins,
Le culte harmonieux de notre gratitude.
Non contents d'imiter les oeuvres de leurs mains,
Nous les célébrerons devant la multitude. . . .

Je m'en irai content. Puisque j'aurai tracé
Mon sillon dans la plaine où Dieu m'avait placé,
Et puisque le repos du serviteur fidèle
M'attendra dans la Paix solide du cercueil,
Je bénirai la mort, et sur un geste d'elle,
Je saurai l'accueillir d'un fraternel accueil.

Légendes de Percé

Par Claude Melançon

Présenté par Marius Barbeau, M.S.R.C.

(Lu à la réunion de mai 1922)

Le merveilleux est universel, mais l'imagination populaire ne s'en est pas inspirée partout également. Il est des lieux où chaque fontaine, chaque buisson, chaque pierre, semblent cacher une légende terrible ou gracieuse et d'autres où le voile de mystère et de poésie qui enveloppe les êtres et les choses est encore à peine soulevé.

Percé est probablement l'un de ces pays de rêve que l'on pourrait comparer au château de la Belle-au-Bois-Dormant. Tout un monde pittoresque et poétique y dort depuis des siècles au sein d'une nature grandiose, attendant toujours le coup de baguette magique qui le fera revivre dans les imaginations.—De temps à autre, une légende franchit le cercle enchanté, un conte se réveille dans la mémoire d'un pêcheur de la côte, un souvenir curieux se met à vagabonder; mais si l'on ne se hâte de les recueillir, légende, conte et souvenir se volatilisent bientôt dans l'oubli, comme ces légers brouillards blancs qui s'enroulent un instant autour du Rocher Percé.

La tradition orale a conservé très peu de ce merveilleux fugitif et les légendes qui suivent n'ont pas été recueillies sous leur forme présente. Un vague récit de pêcheur, un mot populaire, une étymologie curieuse les ont d'abord inspirées, puis l'imagination a fait le reste. . . .

Le Poisson de Saint-Pierre

Pierre Lamothe et Archange Boissel étaient de moitié de ligne: autrement dit, ils partageaient les profits de leur pêche. Ils étaient bien les deux hommes les plus différents que l'on puisse rencontrer. Pierre, grand, fort, brutal et tapageur était tout l'opposé d'Archange, petit, malingre, doux et tranquille.

Probablement à cause de ce contraste et parce qu'ils s'aimaient mutuellement sans se l'avouer, ils s'entendaient admirablement. Certes, ils se disputaient, et souvent, mais toujours pour la même raison:

Pierre était le plus grand "sacreur" de la côte et Archange le lui reprochait:—"Tu nous amèneras le malheur," disait-il. Alors Pierre s'emportait et jurait davantage.

Un jour qu'ils pêchaient au large, chacun d'un côté de la barque, comme c'est l'habitude, Pierre s'écria tout à coup: "Tiens! une goberge? La gueuse! elle tient mon" ain "dans son" gau!"[1] . . .

Il fallait enlever l'hameçon. Pierre voulut prendre la goberge par la tête; elle lui glissa des mains. Un gros juron avertit Archange de son échec. Une seconde tentative, aussi malheureuse, amena un second juron et comme le pêcheur ne réussissait toujours pas à récupérer son engin, tout le vocabulaire y passa. Archange, qui hâlait une énorme morue de l'autre côté de la barque, lui jeta par-dessus l'épaule:

—"Au lieu de blasphémer, tu ferais mieux d'invoquer ton patron qui est aussi celui des pêcheurs!"

—"Si Saint-Pierre est capable de prendre cette maudite goberge dans ses mains," réplique l'autre, "je jure par ma mère, une sainte femme, de ne plus sacrer de ma vie."

A peine avait-il fait ce serment que Saint-Pierre en personne, enveloppé dans un grand manteau brun, comme dans les tableaux des églises, parut à ses cotés. Sans dire mot il prit la goberge par la tête, arracha l'hameçon, la tendit à Pierre et disparut.

"—Nom de . . ." commença Pierre, quand il fut revenu de sa stupeur; mais il se reprit à temps et appela Archange pour lui conter le miracle. Son compagnon se montra sceptique:—"Tu penses que c'est une" menterie "dit Pierre, eh bien! regarde," et il lui montra la goberge au fond de la barque. De chaque coté de la tête, à l'endroit où les doigts du saint l'avait saisie, elle montrait deux taches noires, preuve du miracle qui venait de s'accomplir.

Depuis toutes les goberges se distinguent des morues par ces deux taches miraculeuses et c'est en souvenir de cet événement que les pêcheurs les nomment "les poissons de Saint-Pierre."

Le Cormoran Enchanté

Tout en relevant ses filets étendus sur les "*tangons*," le père François le Gascon grommelait: "Satanés cormorans! Ils ont encore tout mangé ma "*boitte*." Je vous demande un peu pourquoi le gouvernement protège ces bestioles-là! Depuis qu'il est défendu de les tuer, pas moyen de garder un hareng dans les filets. Ces messieurs ne se donnent même plus la peine de pêcher et se nourrissent à nos dépens. Satanés cormorans! On avait pourtant assez de mal à s'en débarrasser autrefois. Vous savez qu'ils ont un sort ces oiseaux-là? Du moins, celui qui a fait "*damner*" si longtemps mon défunt père en

[1]Les pêcheurs nomment "gau" l'estomac de la morue.

avait un. Vous ne connaissez pas cette histoire? . . . Ben! je vas vous la conter. . . .

Dans ce temps-là, mon père étendait ses filets près du Pic d'Aurore. Moi j'ai mis les miens devant le Cap Barré; c'est plus chanceux. Tous les soirs il allait les relever avec le "*flatte*" et tous les soirs que le Bon Dieu amenait, il était sûr de voir *resoudre* un gros cormoran avec un de ses harengs dans le bec. Au commencement il disait trop rien, mais à la longue il s'est "choqué." "Je vais lui flanquer un coup de fusil," qu'il disait, "ça lui apprendra à venir voler le *butin* du pauvre monde." Mais il remettait toujours.

Un bon soir, il trouve deux harengs a demi mangés dans son filet. C'est tout ce que le cormoran lui avait laissé. Alors il se décide. Le lendemain, il emprunte le fusil à outardes de Mathieu, le père du petit Osias, l'homme de *grave* de chez Robin, et il va relever ses filets, sûr de trouver son cormoran en train de s'en mettre plein la falle. Comme de bonne, au premier tangon, le cormoran *resout* avec un beau hareng. Mon père prend son temps, épaule, tire, boum! Quand la *boucane* est partie, il regarde. . . . Le cormoran avalait tranquillement son posison. Le coup de fusil ne l'avait pas dérangé. Ca étonnait mon père, car il passait pour le meilleur tireur de la côte. Vite il recharge, *nage* un peu pour approcher le *flatte*, vise en plein dans la tête, et lâche son second coup.

Cette fois, le cormoran disparut. Je l'ai blessé, dit mon père. Pas de danger! Voilà qu'au bout d'une minute le cormoran revient avec un autre hareng. . . . Mon père nous a raconté qu'en voyant ça, les cheveux lui en sont venus *drettes* sur la tête. Il pensait que c'était le *guiable* tout pur.

Quand il conta cette histoire au village, tout le monde voulut voir le cormoran enchanté et essayer sa chance. Le lendemain ils partirent douze fusils. De la grève on entendait la fusillade. On aurait dit que la falaise s'écroulait. . . . Après avoir tiré comme cà pendant une heure, ils revinrent au village la tête basse et pas fiers, en disant à mon père qu'il fallait se résigner et qu'il ne pourrait jamais rien contre un cormoran enchanté. . . . Ça vexait mon père de les entendre parler ainsi. Il ne dit mot, mais se promit bien qu'il l'aurait cet oiseau de malheur. Chaque soir, il allait se mettre à *l'espère* dans une grotte de la falaise. Le cormoran savait qu'il était là, mais si vous croyez que ça le dérangeait! . . . Il venait toujours faire un petit tour de ce coté pour faire enrager le *bonhomme* et, quand il avait attrapé un coup de fusil, il plongeait chercher un hareng. C'etait sa manière de se venger du plomb. . . .

Mon père en perdait le goût de la soupe. La nuit il devait rêver car ma mère l'entendait marmotter: "Je te tuerai cormoran! je te tuerai!"

Sur les entrefaites, l'on décida de descendre la statue de la bonne Saint-Anne qui était sur la Table-à-Roland. Nous autres, les pêcheurs, nous n'aimions pas ça. Nous étions habitués à la voir, là-haut, sur la montagne et quand nous étions en mer, elle nous protégeait. Le pire c'est qu'on l'a vendue. Elle était en plomb, comme vous savez, et les anglais l'ont achetée pour faire des *tourloutes*. Mon père était là quand ils l'ont *débitée*. Le pauvre homme pensait toujours à son cormoran et *jonglait* des moyens de le tuer. Le plomb de la statue lui donna une idée. . . . Il en prit un petit morceau pour mettre dans son fusil. . . . Ce soir là il se mit en *l'embusque* comme de coutume; *eh bien!* du premier coup il tua le cormoran. . .

Vous voyez bien qu'il était enchanté, cet oiseau-là! . . .

La Gougou

Pierre-Marie, natif de Bretagne, s'était fait embaucher à quinze ans par le patron Cardurec, propriétaire de la "Reyne Anne," une solide barque qui faisait la pêche sur les côtes de la Gaspésie. A son premier voyage à Percé, il entendit parler de la Gougou dont les indiens faisaient des descriptions épouvantables et un grand désir de voir cette bête monstrueuse le tourmenta. Un jour que son patron était occupé à calfreutrer son bateau, il déroba un canot indien et traversa à l'ile Bonaventure, repaire du monstre.

Son escapade ne tarda pas à être découverte et le propriétaire du canot se mit en quête de son embarcation avec quelques autres sauvages. A deux milles au large de l'île ils découvrirent Pierre-Marie évanoui au fond du canot à la dérive. Ramené au village, l'enfant raconta son aventure:

Ayant atterri à la baie Paresseuse, du côté sud de l'île, il avait tiré le canot sur le sable de la grève, puis s'était enfoncé prudemment dans un bois de génèvriers.

Il marchait depuis quelque temps, prenant confiance à chaque pas, quand tout à coup il entendit derrière lui un bruit comme en ferait un gros soufflet de forge. En même temps une odeur de charnier se répandait dans l'air. Pierre-Marie se retourna. Sainte-Vierge! A moins de dix toises de lui se tenait la plus effroyable bête qu'on puisse imaginer. Elle ressemblait de corps à un lion marin, mais était beaucoup plus énorme. Sa face horrible, ridée comme celle d'une vieille sorcière indienne, était ornée de longues dents menaçantes qui la rendaient encore plus terrible. Deux yeux méchants brillaient derrière les poils jaunes qui lui pendaient sur le museau. Une grosse langue rouge, dégoûtante de bave, se promenait sur ses babines sanglantes.

Pierre-Marie ne perdit pas plus de temps à examiner la Gougou; poussant un cri d'effroi, il prit sa course à travers le bois, poursuivi par la bête dont il croyait sentir l'haleine puante dans son cou.

Il courait droit devant lui, le petit Pierre-Marie, sans s'occuper des branches qui le frappaient au visage en passant, et trop effrayé pour réaliser qu'il s'en allait au hasard. Il comprit sa faute en débouchant du bois. A deux pas de lui c'était la falaise abrupte et, trois cents pieds plus bas, la mer. Derrière venait la Gougou avec un bruit d'ouragan.

Mourir pour mourir pensa le petit mousse, autant se noyer qu'être dévoré par cette affreuse bête. La Gougou était sur lui. Pierre-Marie après s'etre signé et avoir recommandé son âme à la Vierge, fit les deux pas qui le séparaient de l'abime, ferma les yeux et sauta. . . . Miracle! A peine eut-il quitté la bord de la falaise qu'il sentit de grandes ailes le supporter et le déposer tout doucement dans un canot. Là, il perdit connaissance. C'était tout ce qu'il savait et le patron Cardurec, même en le menaçant du chat à neuf queues, s'il ne disait la verité entiere, n'en put tirer d'avantage.

Des pêcheurs louèrent les "margaux" de ce sauvetage miraculeux, mais on blâma ces esprits forts et la croyance générale s'arrêta à l'intervention des anges. Pierre-Marie reçut le surnom "d'enfant de la vierge" et par la suite il ne manqua jamais, de retour de ses voyages à Percé, de faire brûler un gros cierge devant la statue de sa protectrice dans l'église de Saint-Malo.

Quand à la Gougou on ne la revit plus jamais. Des indiens prétendirent avoir vu sa carcasse au pied de la falaise, à l'endroit même où le petit mousse avait été porté par des ailes miraculeuses.

Le Prisonnier du Rocher

Il y avait une fois—il y a de cela des lunes et des lunes, un petite indienne appelée Mejiga, la Simple. Son père et sa mère avaient été tués dans une malheureuse expédition des Micmacs.

Personne ne s'occupait d'elle, sinon pour lui confier les travaux les plus durs et les plus répugnants et bien qu'elle fût en âge de se marier, aucun guerrier ne l'avait encore invitée à s'asseoir à son feu.

Son seul ami était un jeune chef huron, fait prisonnier par les Micmacs. Elle allait le voir dans la hutte où il était garotté, mais au lieu de prendre part au jeu cruel de ses compagnes qui lui tiraient les cheveux, lui plantaient des arêtes aigues dans les cuisses et lui versaient des pots d'eau sur la tête en l'appelant: *fils de chien*! elle lui apportait les meilleurs morceaux de viande qu'on lui abandonnait et les lui glissait dans la bouche quand les gardes avaient le dos tourné.

Cette générosité eut raison du stoïcisme du jeune indien qui la remercia un jour d'un regard.—C'était la première fois qu'un homme la regardait sans se moquer ou se détourner et en échange de ce signe de reconnaissance, Mejiga donna son amour à Tiotiaké, le huron.

Elle décida de le faire évader et de s'enfuir avec lui . . . s'il y consentait. Mais avant qu'elle eut adopté un plan, le chef de la tribu des Micmacs fit comparaître devant lui le prisonnier.

On approchait de l'équinoxe, temps consacré à l'adoration du soleil et la loi indienne défendait d'attacher les prisonniers au poteau de torture durant ces jours sacrés. Negum,—c'était le nom du vieux chef, pensa que l'honneur de convertir un huron à son culte valait bien le plaisir de le faire mourir dans les tourments. Il offrit à Tiotiaké de le rendre à la liberté s'il adorait le soleil, dieu des Micmacs.

"—Le Grand Esprit est mon dieu," répondit dédaigneusement le jeune huron. Furieux, le vieux Negum ordonna de l'exposer, "devant le dieu a qui il refusait de rendre hommage" et de le laisser sans eau et sans nourriture.

On choisit pour lieu du supplice le Rocher Percé, accessible seulement au moyen d'une grossière échelle construite par les indiens qui dénichaient au printemps les oeufs de goélands.

Bravant la périlleuse ascension. Mejiga réjoignit Tiotiaké, le second soir. Tout était prêt pour l'évasion: un canot avec des vivres attendait au bas de l'échelle.

Que se passa-t-il ce soir là sur le Rocher? Le lendemain on trouva sur la grève le corps du prisonnier huron avec un couteau dans le dos. Méjiga était disparue.

La légende veut que le Grand-Esprit, touché de son désespoir, l'ait métamorphosée en goéland pour lui faire oublier la mort tragique de son ami, égorgé sous ses yeux, mais elle, inconsolable passe ses nuits à chercher Tiotiaké en se lamentant.

Onawada

On était au printemps, saison consacrée au mariage chez les indiens de Percé. Les jeunes guerriers à qui leurs prouesses à la guerre et à la chasse avaient mérité d'allumer leurs propres feux, s'étaient mis en quête d'une compagne. Déja, plusieurs avaient payé la dot de maïs, de poisson séché et de peaux de castor.

A la source où l'on puisait l'eau pour la tribu, au champ de maïs, autour des pilons de pierre qui servaient à broyer le grain, c'était l'unique sujet de conversation des femmes.

Seule Onawada, la Blanche Mouette, fille unique du chef Wokwis, restait indifférente. Sa conduite était inexplicable. Elle avait refusé d'épouser les plus braves guerriers de la tribu. N'kum, le héros de vingt combats que le chef avait désigné au conseil pour être son successeur, s'était vu, à sa honte, éconduire comme les autres.

Wokwis se désolait. Les anciens le blamaient de ne pas imposer à sa fille un guerrier de son choix, comme le lui permettait la coutume, et Onawada le menaçait de se tuer sous ses yeux s'il forçait sa volonté. Le vieux chef hésitait entre son orgeuil et son amour paternel.

Maintes fois il avait interrogé la Blanche Mouette sur ses sentiments, mais jamais il n'avait pu en obtenir de réponse satisfaisante.

La vérité c'est que Onawada aimait Natawi, le Lièvre, et en était aimée. Si elle tenait la chose secrète c'est que l'aveu de cet amour eut entrainé la mort immédiate de son ami. Le Lièvre avait mauvaise réputation parmi la tribu. On l'accusait de jeter des sorts. Un malheur affligeait-il la bourgade? il en était aussitôt tenu responsable; en revanche, on oubliait facilement les guérisons qu'il opérait chaque hiver à l'aide d'infusions d'herbes et d'écorces d'arbre.

Les Micmacs avaient un autre grief contre Natawi: il ne suivait jamais les guerr'ers dans leurs expéditions sanglantes; tout au plus consentait-il à porter des messages aux tribus alliées. La rapidité avec laquelle il s'acquittait de ces missions lui avait valu ce nom de "Lièvre."

Son agilité n'avait d'égale que sa force. Les indiens tout en le détestant avaient apris à le respecter depuis le jour où ils l'avaient vu lutter avec un énorme ours noir et le terrasser. Leur étonnement avait été à son comble quand, un peu plus tard, ils virent l'ours, apprivoisé par Natawi, suivre son maître comme un chien. Cet exploit les avait confirmés dans leur croyance que le Lièvre était sorcier.

Onawada partagea les préjugés de sa tribu jusqu'au jour où, dans la forêt, elle vit le Lièvre. Il lui avait souri mais n'était pas venu à sa rencontre. Pourtant, lorsqu'elle se retira, elle eut la certitude qu'un homme la suivait et que cet homme était le Lièvre.

Cette poursuite discrète ne lui déplut pas: Natawi était beau, il lui avait paru nullement féroce, plutôt différent des autres indiens et une sympathie mystérieuse éprouvée en le voyant, avait dissipé tous ses préjugés. Elle retourna dans le bois, le lendemain.

Le Lièvre paraissait l'attendre. Il avait attaché son ours au tronc d'un bouleau qui pliait sous les efforts de la bête pour se libérer et s'était assis sur la mousse. Onawada vint s'accroupir à quelques pas devant lui. Ne sachant que se dire, ils restèrent ainsi à se regarder jusqu'au soleil couchant. Leurs yeux exprimaient leurs sentiments, très simples et très naifs.

La Mouette Blanche revint régulièrement à ce rendez-vous. Chaque fois elle s'asseyait plus près et Natawi savait qu'elle lui était fidèle.

Un jour elle déposa à ses pieds un sac à tabac brodé de ses mains. C'était un cadeau de fiançailles. Le Lièvre enleva son collier de griffes d'ours et le passa au cou de la jeune fille. Puis il l'entraîna dans sa demeure, une caverne habitée autrefois par l'ours qu'il avait apprivoisé.

C'est là que peu de jours avant la grande cérémonie du mariage Onawada et Natawi s'épousèrent selon le rite indien, à l'insu de toute la bourgade. La Blanche Mouette, comptant tout expliquer à son père quand elle ne serait plus menacée d'épouser N'kum, ne retourna pas auprès des siens. Le Lièvre l'assurait que leur retraite était sûre.

Il se trompait. Inquiet de sa fille, Wokwis assembla ses guerriers et organisa une battue. Ce fut N'kum qui releva la double piste des jeunes gens et mena la bande à la caverne. L'entrée en était gardée par l'ours de Natawi, mais depuis son servage la bête était devenue couarde. En voyant cette troupe armée, elle n'eut que l'instinct de se dérober aux lances qui la menaçaient en grimpant sur la corniche qui surplombait l'entrée de la caverne.

Le chemin étant libre, la bande allait se précipiter, quand une grosse roche, minée par l'eau, céda sous le poids de l'ours, entrainant à sa suite toute une avalanche qui bloqua complètement l'entrée. N'kum qui, dans sa hâte de venger sur le Lièvre l'injure reçue d'Onawada, s'était trop avancé, disparut sous l'amas de terre et de roches.

Ainsi finit l'idylle d'Onawada et de Natawi, qui connurent la mort aussitôt que l'amour et dont le vieux chef Wokwis, porta le deuil en vermillon, après leur avoir pardonné.

La caverne murée dans laquelle ils reposent s'aperçoit encore de la mer et cette fausse entrée en forme de portail, ainsi que deux énormes rochers en forme de tour, ont fait donner à la Montagne le nom de "Donjon."

Les Retours de l'Histoire. A propos de Louisbourg et d'un livre recent

Par l'honorable RODOLPHE LEMIEUX, M.S.R.C.

(Lu à la réunion de mai 1922)

Certaines familles anglo-canadiennes sont tolérantes par tradition. Elles ne s'arrêtent pas aux préjugés de race. Courtoises par tempérament, recevant une instruction toujours soignée, elles jouissent de la largeur d'esprit indispensable aux relations harmonieuses qui doivent former la base de notre vie nationale. Plusieurs d'entre elles sont les piliers de la société canadienne. Leurs sympathies évidentes pour l'élément français ont depuis longtemps conquis notre affection.

La famille McLennan est de ce nombre. Montréal est son berceau. Ecossaise, comme l'indique son nom, elle est imbue de ce libéralisme qui consiste à aimer la liberté pour elle-même autant que pour soi. Elle a toujours recherché le beau, le bon et le bien et ne s'est jamais préoccupée de choses malsaines.

Deux membres distingués de cette famille, l'honorable M. John S. McLennan, sénateur, et M. Francis McLennan, conseil du roi, du barreau de Montréal, sont bien connus dans nos cercles intellectuels. Ce sont des chercheurs. Le Canada français les intéresse. Les travaux historiques auxquels ils consacrent leurs loisirs sont libres de toute prévention. Je rends hommage à leur patriotisme, leur modération, leur talent, et comme Canadien-français dont les ancêtres maternels sont de race acadienne, je ne puis me défendre d'un très vif sentiment de reconnaissance pour les nombreux témoignages d'amitié qu'ils ne cessent de nous donner dans leurs écrits.

M. le sénateur McLennan est l'auteur d'un livre de grand mérite[1] sur l'ancienne et héroique ville de Louisbourg où se sont livrés, en 1745 et 1758, deux batailles de premier ordre pour la suprématie de l'Angleterre en Amérique. Il a décrit dans un travail de longue haleine la fondation, le progrès et les luttes de cette forteresse construite au prix de trente millions de francs, par la France, au XVIIIe siècle, pour conserver son empire colonial sur notre continent. Les archives nationales de Londres, Paris et Ottawa ont été mises à sa disposition.

M. McLennan aime le pays d'Evangéline. "L'Acadie, dit-il, fut la première colonie européenne en Amérique du Nord. Son histoire touche à l'extraordinaire: elle est faite de la négligence de la mère-

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[1]*Louisbourg, its rise and fall.*

patrie, des guerres intestines entre les propriétaires de ses forêts et des ravages de ses colonies en butte aux attaques des colons anglais. Ces attaques commencèrent avec l'incursion d'Argall, le Virginien, en 1613, et ne cessèrent qu'en 1710, quand l'Acadie fut conquise par les troupes de la Nouvelle-Angleterre soutenues par une flotte anglaise. Son passé attire la pitié. On est étonné que sa principale ville, Port-Royal, ait pu survivre et que 2400 Acadiens aient vécu en d'autres endroits sur des terres tellement fertiles qu'elles ont excité la cupidité des envahisseurs."

Le 2 septembre 1713, au lendemain de la guerre de la succession d'Espagne, après la signature du traité d'Utrecht, Joseph-Ovide de Brouillant, Chevalier de l'Ordre Militaire de Saint-Louis, commandant du Semslack, débarquait 116 hommes, 10 femmes et 23 enfants au Havre à l'Anglois, Cap-Breton, qui s'appelait alors l'Isle Royale. Le nom de cet endroit fut changé en celui de Louisbourg. Les nouveaux colons, chassés de Plaisance, sur l'ile de Terreneuve, qui venait d'être cédée à l'Angleterre, apportaient quatre bateaux-pêcheurs, quelques outils, quelques animaux et peu de provisions. Placés entre la forêt et l'océan, leur perspective n'était pas brillante. Ils se mirent résolument à l'oeuvre et se construisirent les habitations dont ils avaient besoin. Le major l'Hermitte, ingénieur qui les accompagnait, avait en vue l'établissement d'une forteresse. Appuyé de Vaudreuil et de l'intendant Bégon, il obtint du roi l'autorisation de fortifier la place sans égard aux dépenses. Des travaux considérables furent exécutés. Un commerce important se développa. Les exportations et les importations en Acadie, au Canada, dans la Nouvelle-Angleterre, aux Indes Occidentales et en France, se chiffrèrent, en tout, à près de trois millions de francs. Une population laborieuse avait réussi, grâce à d'énormes sacrifices, à fonder une ville commerciale, fortifiée et pleine d'avenir à l'entrée du Saint-Laurent. Si le progrès de Louisbourg n'eut été entravé par l'incurie de la cour de Louis XV et l'incompétence des ministres, la France aurait probablement conservé le Canada et cette ville serait aujourd'hui une métropole sur le continent américain. Mais elle devait tomber victime des guerres européennes.

Lorsque, en 1744, la France déclara la guerre à l'Angleterre, la marine française s'était quelque peu relevée de ses ruines quoiqu'elle fut encore très au-dessous de la marine anglaise. La lutte devait se décider dans le Nouveau-Monde. Le 23 mars 1745, les colonies anglo-américaines, obéissant aux ordres de l'avocat Shirley, gouverneur du Massachusetts, armèrent 4070 hommes sous le commandement de Pepperell et Wolcott. Le commodore Warren leur amena de Londres quatre vaisseaux et tous se rendirent à Louisbourg dont ils s'emparent le 26 juin après une résistance acharnée. M. McLennan raconte la lutte dans ses détails, rend hommage à la bravoure des assiégés et blame en termes sévères la conduite des soldats anglais qui se rendirent coupables de déprédation.

Les vainqueurs ne devaient pas jouir longtemps de leur victoire. L'une des clauses du traité d'Aix-la-Chapelle signé le 18 octobre 1748, les força de remettre le Cap-Breton à la France. Ils y consentirent de très mauvaise grâce, et les Français qui avaient évacué Louisbourg revinrent.

Une paix soumise à de telles conditions ne pouvait durer. L'esprit de guerre se réveilla à la reprise de la concurrence française en Amerique. Une sorte de *delenda est* fut prononcé par les colonies anglaises contre la Nouvelle-France. L'opinion publique en Angleterre demandait la destruction de l'empire colonial de Louis XV. Newcastle écrivait en 1754: "Les Français réclament la possession de toute l'Amérique du Nord, excepté la lisière du littoral, dans laquelle ils voudraient resserrer toutes nos colonies; mais c'est là ce que nous ne pouvons ni ne voulons souffrir." Le 25 mars 1755, le roi Georges demandait au parlement, qui l'accorda, un subside d'un million de livres sterling "pour sauvegarder les justes droits et les possessions de sa couronne en Amérique." L'amiral Boscawen reçut l'ordre de se rendre sur les côtes de l'Acadie, d'y rallier les forces navales en station à Halifax, puis de s'établir en croisière devant le port de Louisbourg. La marine française était alors insuffisante et mal commandée tandis que la marine anglaise, sous les ordres de Byng, Boscawen et Hawke, inspirés par le génie de William Pitt aspirait dès lors à la suprématie des mers. Pitt rêvait déja le vaste empire maritime et tenait la flotte en perpétuelle activité. Veritable impérialiste, il associa les colonies à l'action de la métropole et leur envoya toujours des renforts. En 1757, il bloqua à Toulon la flotte française de la Méditerannée. En 1759, il devait détruire celle de Brest et se trouver maître de l'Atlantique.

Le premier juin 1758, plus de 40 vaisseaux de ligne et 100 transports portant 14,000 hommes aux ordres du général Amherst et du colonel Wolfe, étaient devant Louisbourg pauvre de munitions et défendu seulement par 3,000 réguliers et six cents miliciens et sauvages commandés par Augustin de Drucourt. Six vaisseaux de ligne et sept frégates françaises portant 3,000 matelots étaient ancrés dans le port. Les fortifications ayant été négligées, tombaient en ruines. Le bombardement commença le 8 juin et dura jusqu'au 27 juillet. C'est dire que les assiégés se battirent avec beaucoup de courage. Madame

Drucourt, femme du gouverneur, s'illustra par son héroisme. Elle fut de tous les grands combats, parcourant les remparts sous le feu de l'ennemi, tirant elle-même le canon, pansant les blessés et récompensant les artilleurs les plus adroits. Les vaisseaux français coulèrent, les fortifications furent réduites en poussière, les batteries rasées. Louisbourg n'étant plus qu'un monceau de ruines tomba une seconde fois sous les drapeaux anglais. Cette bataille coûta près de 600 hommes à l'Angleterre et à la France, environ 800 tués ou blessés. Il y eut de grandes réjouissances à Londres. Mais il ne faut pas oublier que le courage de Drucourt et de sa vaillante garnison avait pour le moment sauvé le Canada, car Amherst et Boscawen, trop affaiblis pour remonter le Saint-Laurent, durent remettre à plus tard leur expédition contre Québec. L'année suivante, en 1759, c'est de Louisbourg que partit la flotte qui devait donner le coup décisif aux armées de la Nouvelle-France. Elle s'assembla en mai et fit voile le 6 juin.

Le livre de M. McLennan contient une description des fortifications de Louisbourg, une liste complète des officiers qui les défendaient, plusieurs plans des sièges de 1745 et de 1758, les livres du bord des vaisseaux anglais, les biographies et les rapports de leurs commandants et la correspondance officielle entre les autorités françaises et les gouverneurs de l'Ile Royale. Il fournit de plus dix-neuf illustrations hors texte et un excellent dessin en couleur de la ville de Louisbourg. L'auteur jette de la lumière sur quelques points controversés et met au jour un grand nombre de documents inédits. Il a écrit une histoire complète de cette malheureuse ville dont l'existence sous le drapeau français ne dura que quarante-cinq ans (de 1713 à 1758). Un tel apport au domaine littéraire du Canada mérite, je crois, d'être signalé. Ce volume prendra place avec les oeuvres de Parkman, Hannay, Garneau, Edouard Richard et Ferland. Puisque nous n'octroyons aucun prix pour les oeuvres de ce genre, nous ne pouvons au moins refuser à M. McLennan le tribut de notre reconnaissance et de notre admiration. Mais il n'a guère besoin de nos suffrages; son nom est désormais immortel parmi les écrivains canadiens et ce livre est le monument le plus solide qui puisse s'élever à sa mémoire.

Louisbourg ne fut pas seul à souffrir de l'inefficacité de la marine française. En 1755, la France ne comptait que 71 vaisseaux armés de 4790 canons tandis que l'Angleterre avait 131 vaisseaux et 8722 canons. Lorsque Louis XIV remplaça Colbert par Louvois, il abandonna pour ainsi dire les colonies américaines. Sous le Régent et dans la jeunesse de Louis XV, les cardinaux-ministres Dubois et Fleury, partisans outrés de la paix, n'osèrent pas augmenter la flotte de crainte d'offenser l'Angleterre. Maurepas voulut changer cette politique, mais il en était incapable parce que les extravagances du roi avaient épuisé les sources de revenu. Madame de Pompadour finit par l'envoyer en exil. C'est à cette situation que l'Acadie doit ses malheurs. Aucun pays ne promettait de mieux réussir que cette colonie de Charnizay et de Poutrincourt assise sur un sol fertile et possédant des ports de mer avantageux. Son histoire, cependant, est une série d'infortunes. Fondée par le huguenot De Monts en 1605 (trois ans avant Québec), la colonie acadienne n'aurait probablement pas eu de si mauvais jours si, trois ans plus tard, le roi d'Angleterre n'en eut inclus une partie dans la charte concédée aux colonisateurs de la Virginie. Une série de prises, de redditions et de reprises eut lieu. En 1613, c'est Argall qui détruit Port-Royal et est bientôt forcé de l'abandonner. En 1654, les Anglais du Massachusetts forcent Latour à abandonner son fort sur la rivière Saint-Jean et s'emparent encore de Port-Royal. Survient le traité de Bréda, en 1667, en vertu duquel l'Acadie est remise à la France. En 1690, Sir William Phipps, avec une flotte de six vaisseaux et 656 hommes s'empare encore de Port-Royal et la domination française prend fin pour toujours en Acadie. Le traité d'Utrecht, signé en 1713, cédait à l'Angleterre ce pays ainsi que la baie d'Hudson et Terreneuve.

Le pauvre peuple acadien, ballotté entre deux allégeances, victime des déprédations de quelques-uns de ses gouverneurs, trahi quelquefois par certains officiers malhonnêtes, en butte aux intrigues des commerçants, n'en continuait pas moins sa marche vers le progrès. Grâce à la richesse du sol due en grande partie aux aboiteaux dont les Acadiens furent les inventeurs, ils avaient établi des fermes productives et des vergers qui furent la base d'une industrie encore rémunérative. Tracassés de toute part et persécutés par le fanatisme religieux, ils triomphaient toujours de leurs ennemis. Rien ne pouvait les décourager. Leurs terres étaient les plus belles, leurs habitations les plus coquettes et leurs villages situés en des endroits pittoresques excitaient l'envie des colons anglais. Un tel peuple ne pouvait être conquis par les petites persécutions, les ennuis ou les importunités. On voyait d'un mauvais oeil cette colonie française grandir en plein centre d'un pays anglais. C'est là la cause de la déportation acadienne. Depuis longtemps cette tache dans l'histoire coloniale de l'Angleterre est discutée. Parkman a cherché à en excuser, sinon exonérer, le gouvernement de la métropole. Edouard Richard en a jeté toute la responsabilité sur les épaules de Lawrence. Mais il semble aujourd'hui, d'après une plaquette des plus intéressantes que vient de publier M. Placide Gaudet, que le gouvernement lui-même ne fut pas étranger à cet acte de persécution.

Il y a près de deux siècles que le "grand dérangement" a eu lieu. Nous devons à nos ancêtres de ne pas en perdre le souvenir, mais il ne faut pas en faire une cause de ressentiment perpétuel contre la Grande Bretagne. L'union des deux races est essentielle à notre pays. J'admire donc le geste de Lady Burnham et des journalistes anglais qui ont inauguré à Grand Pré, le 29 juillet 1920, un monument à Evangéline. Comme l'a dit si justement cette femme distinguée: "L'histoire nous a montré sous un nouveau jour le passé de l'Acadie. Quelque puisse être le fond de cette épisode, je suis une femme et je la regarderai toujours comme l'une des plus pénibles de nos annales. Dieu merci! ces jours cruels sont passés et du sort d'Evangéline est venue une vague de sympathie que l'oeuvre du temps a accentuée. A Evangéline nous pouvons dire: Tu es le soleil des jours anciens et tes rayons brillent sur nos têtes. Sous de tels rayons, pleins de beauté et de promesse, la haine du passé est morte, il ne reste que l'âme des deux races et cette âme mérite le respect et l'admiration du monde entier."

M. McLennan ne voit que les bons côtés de notre histoire. Les impressions des hommes mêlés aux événements qu'ils décrivent ne l'influencent guère. Il n'ajoute pas trop foi aux accusations systématiquement portées contre les Acadiens. Bref, il ne croït pas qu'il y ait jamais eu au Canada une race supérieure. Il tend la main aux descendants des Français et semble nous inviter à une fête de mutuelle admiration.

Les deux sièges de Louisbourg ont laissé plus de regret que de ressentiment. Drucourt a capitulé aprés une lutte loyale. Quand j'aperçois dans la salle du chateau de Ramezay la vieille cloche paroissiale de cette forteresse acadienne, je me sens absorbé dans l'idéal qui a inspiré la lutte séculaire pour la conquête d'un continent. La poésie de Longfellow a ouvert la voie des pardons mutuels. C'est dans la langue de Lawrence que nous avons lu le récit idéalisé des malheurs d'Evangéline. Mais nos poëtes canadiens ont aussi oublié les anciennes haines pour ne se rappeler que le côté patriotique du martyloroge acadien. De Louisbourg, il nous reste encore le beffroi de l'église. C'est là un souvenir qui ne périra jamais. Nérée Beauchemin, qui fut appelé le plus grand poëte du Canada, nous dit que cette cloche

Rutile à nos yeux comme l'or.

. . . .

A présent, le soir, sur les vagues,
Le marin qui rôde par là

Croit ouïr des carillons vagues
Tinter *l'Ave Maris Stella.*

. . . . . .

Oh! c'était le coeur de la France
Qui battait à grands coups alors
Dans la triomphale cadence
Du grave bronze aux longs accords!

. . . . . .

En nos coeurs tes branles magiques,
Dolents et rêveurs, font vibrer
Des souvenances nostalgiques,
Douces à nous faire pleurer.

Le Regiment de Carignan

Par FRANCIS-J. AUDET

Présenté par l'honorable PASCAL PORRIER, M.S.R.C.

(Lu à la réunion de mai 1922)

Le huitième volume des *Mélanges Historiques* de M. Benjamin Sulte, annoté et publié par M. Gérard Malchelosse, vient de paraître. Il contient une étude soignée sur le régiment de Carignan. Ce volume est l'un des plus intéressants de ceux parus jusqu'à date et M. Sulte mérite de chaleureux éloges pour ce travail qui lui a coûté beaucoup de peine et de recherches.

"Ce régiment, fameux dans notre histoire, dit M. Malchelosse dans sa préface, a dû compter quatre-vingt-seize officiers, si nous y joignons ceux des quatre compagnies de M. de Tracy. Or M. Sulte en mentionne près de quatre-vingt-dix."

A part ceux de l'état-major, M. Sulte nous donne le nom de quatre-vingt-quatre officiers, soit vingt-quatre capitaines, vingt-deux lieutenants, onze enseignes, dix cadets et sergents et dix-sept officiers de grades inconnus.

M. Malchelosse termine sa préface en espérant "que la découverte d'autres pièces permettra de mener à bonne fin l'oeuvre commencée."

Nous sommes heureusement en mesure de nous rendre au désir exprimé par M. Malchelosse. Nous pouvons dès maintenant ajouter huit noms à la liste de M. Sulte et indiquer le rang d'un des officiers dont le grade était inconnu. Ce sont les capitaines Nauroye et la Brisardière; l'enseigne Manereuille qui servit dans la compagnie Lafouille, et dont on ne connaissait pas le grade; les sergents Larose, dans la compagnie de M. de Loubia; Lafleur, dans celle de M. de Sorel; Laverdure, dans celle de M Latour; Larivière dans la compagnie de M. Dugué; Lapierre, dans celle de M. de Chambly; et Saint-Laurent, dans la compagnie de M. de Saint-Ours.

Quatre-vingt-quatre et huit font quatre-vingt-douze. Il ne manquerait donc plus que quatre noms pour parfaire la liste des officiers de ce régiment si les calculs de M. Malchelosse sont exacts. Mais le sont-ils? C'est ce que nous ne pouvons encore déterminer. Il faudrait pour cela savoir, entre autres choses, combien d'officiers—de sous—officiers surtout—sont retournés en France. Nous ne le savons pas au juste.

En ajoutant deux capitaines aux vingt-quatre de M. Sulte cela fait vingt-six, et comme il n'est venu que vingt-quatre compagnies, il a dû y avoir au moins deux promotions à ce grade durant les trois années que le régiment a passé au pays. Le nombre de lieutenants se trouve ainsi au complet, et les quatre noms qui manquent encore sont ceux d'officiers subalternes, c'est-à-dire, d'enseignes, de cadets ou de sergents.

Pour résumer, nous avons maintenant:

	24 capitaines,
	24 lieutenants, dont 2 furent promus capitaines,
	12 enseignes,
	16 cadets et sergents,
	16 de grades inconnus.
Total	92

En somme le résultat obtenu jusqu'à présent est des plus satisfaisants.

Dans l'histoire du régiment de Carignan (voir Susane, Hist. de l'Infanterie française, tome V, p. 236) il est dit que "en juin 1668, les deux compagnies colonelles, de soixante hommes chacune, débarquaient à La Rochelle." Il semble que M. Susane fait erreur quant au nombre de soldats retournés en France. Il est aussi également inexact de dire que les deux compagnies colonelles rentrèrent en France car un bon nombre de soldats de ces deux compagnies restèrent au Canada comme nous le verrons plus loin. De fait, chacune des vingt-quatre compagnies nous a laissé des colons.

Nous avons dit les deux compagnies colonelles. Comme il n'y avait d'habitude qu'une seule compagnie appelée colonelle dans un régiment, cela demande un mot d'explication (M. Sulte nous l'a d'ailleurs donné dans son livre), et nous ne saurions mieux faire que de reproduire ici, à titre de renseignements supplémentaires, quelques extraits de l'ouvrage nommé ci-haut. Ce récit diffère en quelque points peu importants de celui de M. Sulte.

"Ce régiment, dit M. Susane, est un de ceux dont la destinée a éprouvé les révolutions les plus singulières. Il était d'origine piémontaise, et jusqu'a la paix des Pyrénées il n'a servi dans l'armée française qu'à titre d'auxiliaire. Il fut levé en 1644, par Thomas-Emmanuel-Philibert de Savoie, prince de Carignan, dont il porta le nom; et il avait eu, dit-on, pour noyau, la compagnie des gardes de ce prince célèbre."

Après avoir raconté les diverses campagnes que fit ce régiment, de 1645 à 1652, M. Susane ajoute: "Il joignit alors la cour réfugiée derrière la Loire, et fit partie de la petite armée avec laquelle Turenne ramena Louis XIV à Paris. Il se distingua extrêmement le 2 juillet à la bataille du faubourg Saint-Antoine."

Vers la fin de l'année 1652 le régiment de Carignan s'en retourna au Piémont, où il servit jusqu'en 1658. Après la paix des Pyrénées (1659), le prince de Carignan ne pouvant entretenir son régiment en Savoie, en fit cadeau à Louis XIV. Il fut dès lors admis dans l'armée française.

"Au mois de mai 1665, continue M. Susane, ces compagnies présentant ensemble un effectif de 1000 hommes, allèrent s'embarquer à La Rochelle pour passer au Canada avec un régiment allemand qu'on appelait le régiment de Balthazard. (Voir ce que dit M. Sulte à ce sujet). Le prince de Carignan ne suivit point son régiment en Amérique, et la totalité des troupes embarquées fut placée sous les ordres de M. de Balthazard. On en forma, à cet effet, une espèce de brigade ou de régiment provisoire, qui prit le nom de Carignan-Balthazard, et qui conserva deux drapeaux colonels. La compagnie colonelle de M. de Carignan était la première, et celle de M. de Balthazard la seconde. M. de Balthazard, étant mort la même année fut remplacé par M. de Sallières, qui était le premier capitaine de son régiment. Cela n'apporta d'ailleurs aucun changement à l'organisation du corps, qui prit seulement le titre de Carignan-Salières."

Cette partie du récit du général Susane est sujette à caution, nous dit M. Malchelosse, qui maintient que M. de Balthazard n'est pas mort en 1664, mais vers 1688. Il se serait retiré du régiment en 1659 lors de la réforme de ce corps, et M. de Salières l'aurait alors remplacé. Quoiqu'il en soit, ce point est pour nous sans importance dans le moment. Ce qui nous occupe, c'est tout simplement la découverte de nouveaux noms d'officiers de Carignan.

Un mot de biographie maintenant. Qui étaient ces capitaines Nauroye et la Brisardière?

Le capitaine Nauroye est, croyons-nous, Louis de Niort, sieur de la Noraye, baptisé en 1639, fils de Charles et de Marie Bauger, de Saint-Saturnin de Poitiers, qui épousa, à Québec, le 22 février 1672, Marie Sevestre, fille de Charles, et veuve de Jacques Loyer, sépulturée le 7 novembre 1706 dans l'église de Québec. (Voir Tanguay, I, 180).

Ce La Noraye est-il le soldat recruteur "battant la caisse au coin des rues et carrefours . . ." dont parle M. Sulte à la page 100? Aurait-il, comme son compagnon Philippe Gauthier de Comporté, été promu capitaine? C'est fort possible.

Le 3 novembre 1672, le sieur de La Noraye obtint de Talon la concession "d'une demi-lieue de front sur une lieue de profondeur à prendre sur la rivière Ste-Anne, depuis l'habitation du Sieur Lemoyne. . . ."

Une autre concession en date du 27 avril 1688, signée J. R. de Brisay, marquis de Denonville, et Bochart Champigny, se lit comme suit: "Savoir faisons que sur ce qui nous a esté remonstré par le Sieur de Lessart à cause de Marie Magdelaine Sevestre sa femme, Charles Gaulthier, Marie Denise Sevestre, femme du Sieur Nepveu, et Catherine Gaulthier, veuve de Denis Duquet, que conjointement avec les Sieurs de la Cardonière et d'Artigny, comme représentant feüe leur mère, et Ignace Gaultier et Damoiselle Anne Gaulthier, femme du Sieur Ragueneau, comme représentant Gaulthier, leur père, tous comme héritiers de défunt Mr. Charles Sevestre vivant lieutenant particulier en la jurisdiction de Québec, et Dame Marie Pichon, jadis sa femme, auparavant veuve de feu Gaulthier, il leur appartient par indivis une certaine étendue de terre, prés et bois, de deux lieues de front sur le fleuve Saint-Laurent et deux lieues de profondeur, située entre les terres du Sieur Dautry et celle du Sieur de la Valtrye. . . . Nous, ayant égard à la dite remonstrance et offres, avons les dits lieux, en tant que besoin est ou serait, réuni et iceux réunissons par ces présentes au domaine de Sa Majesté, et en conséquence, en vertu du pouvoir à nous donné par Sa Majesté, avons donné, accordé et concédé . . . aux dits de Lessart, de La Noraye, ès nom et qualités, Charles Gaulthier, Marie-Denise Sevestre, femme Nepveu, et Catherine Gaulthier, veuve Duquet, la dite étendue de terre. . . ."

D'après l'"Armorial du Canada français" de MM. Massicotte et Roy, deuxième série, les armes de M. de La Noraye sont "D'azur, à une bande d'or chargée de cinq fusées de gueules."

Il est assez curieux de constater que le nom de ce capitaine si bien connu ait échappé à l'attention en éveil de M. Sulte, et il nous fait plaisir de le lui signaler.

Le nom de M. de la Brisardière ne paraît pas dans le dictionnaire généalogique de M. l'abbé Tanguay et nous ne l'avons rencontré nulle part ailleurs non plus. Il n'a pas dû rester au pays et nous ne connaissons rien de sa carrière.

Nous sommes encore en mesure d'ajouter quelques précisions aux notes biographiques sur M. de Grandfontaine et de Chambly.

Hector d'Andigné de Grandfontaine était le fils cadet d'Hector de Grandfontaine et d'Anne d'Andigné. Il naquit le 17 mai 1627 à Ruillé-Froid-Fonds, près Château-Gauthier, département de Mayenne. Venu au Canada avec M. de Tracy, il retourna en France en 1668.

Le 25 mars 1669, il accepta le commandement d'une compagnie de cinquante hommes devant servir au Canada. Il fut désigné par Colbert, le 22 juillet suivant, pour recevoir des Anglais le gouvernement de l'Acadie et la restitution de ses forts. Le *Saint-Charles*, à bord duquel il avait fait voile, fut forcé par la tempête de faire route pour Lisbonne où il fut détruit sur les rochers. Rentré en France, M. de Grandfontaine reprit la route de l'Amérique au printemps suivant, à bord du *Saint-Sébastien*, et le 16 juillet, il débarquait à Boston. Le lendemain, sir Thomas Temple lui cédait le gouvernement de l'Acadie. Le 14 août suivant, il arrivait à Pentagouet qui lui fut remis par Richard Walker le lendemain. M. de Grandfontaine fut rappelé en France le 5 mai 1673. Il devint capitaine du *Glorieux*, faisant partie de l'escadre commandée par M. D'Estrée, qui fit voile pour Cayenne en 1676. Il fut blessé au bras à la prise de cette ville. Il s'était fait porter dans une chaise à cause d'un pied malade. L'un des porteurs ayant été tué, M. de Grand fontaine s'élança de sa chaise et se battit vaillamment. Le 27 février 1677, il se faisait casser un bras à Tobago défendu par les Hollandais. Il mourut à Brest le 6 juillet 1696.

M. de Chambly était le fils de Philippe de Chambly et de Louise de Laune. Il avait longtemps commandé le régiment du comte d'Estrade, avant de venir au Canada, et il s'était distingué en Hongrie, dans la guerre contre les Turcs. Nommé le 3 mai 1673, commandant en Acadie, il s'embarqua immédiatement pour Pentagouet, siège de son gouvernement. Le 22 mai 1676, M. de Chambly était confirmé dans sa charge de gouverneur, mais il n'y demeura pas longtemps. Le 3 septembre de l'année suivante, Colbert l'envoyait aux Antilles comme gouverneur; le 24 avril 1679, il devenait gouverneur de la Grenade, et le 7 juin 1680, il passait au gouvernement de la Martinique.

Une note au bas de la page 85 des *Mélanges Historiques* dit que le nom de Montail est écrit Monteuil dans les *Jugements du Conseil Souverain*. Il se lit Monteil dans la liste que possède le Bureau des Archives d'Ottawa.

"Depuis un siècle, dit M. Sulte, en commençant son étude, on demande ce que peuvent être devenus les papiers officiels du régiment de Carignan et, à leur défaut, il a été presque impossible d'aborder l'étude de cette page de notre histoire. Nous avons attendu en vain la découverte des registres, correspondances, bordereaux de paie, etc., qui pourraient fournir sur cette matière, des renseignements précis, copieux et concluants. Puisque la montagne ne vient pas à nous, allons à la montagne."

Nous avons été plus heureux que M. Sulte et que le Prophète d'Allah. Si la montagne n'est pas venue à nous tout entière, une bonne partie s'en est néanmoins détachée—un tiers environ—qui est tombée à nos pieds. Nous n'avons su qu'à nous pencher pour la ramasser! L'effort n'a pas été considérable, mais le résultat n'en est pas moins acquis à l'Histoire.

"Il est impossible, continue M. Sulte (p. 129), d'indiquer les familles canadiennes fondées par des soldats du régiment de Carignan. . . ." Ce qui était impossible hier est devenu la chose la plus facile du monde aujourd'hui, grâce à la découverte d'un ROLLE DES SOLDATS DU REGIMENT DE CARIGNAN—SALIÈRES QUI SE SONT FAITS HABITANS DE CANADA EN 1668. Copie de ce rôle se trouve maintenant aux Archives fédérales. M. Edouard Richard l'avait signalé dans son rapport de 1899 sur les Archives canadiennes, page 31, mais la copie n'en a été reçue à Ottawa que beaucoup plus tard. On le trouve sous la cote D^2, volume 47, pages 3 à 9. Il contient 403 noms. On y rencontre donc un bon nombre de fondateurs de familles canadiennes. Ce rôle mérite certes les honneurs de la publicité. Grâce à lui, les familles canadiennes qui descendent des soldats de ce beau régiment pourront désormais préciser la date d'arrivée de leurs ancêtres au pays. C'est donc une notable addition à nos connaissances historiques et généalogiques.

Il est bon cependant, comme le faisait remarquer M. Richard, de n'être pas trop enthousiaste. On sait que lors de leur entrée au régiment, les recrues étaient baptisées par les camarades d'un sobriquet qui restait généralement attaché à leur nom et qui, bien souvent, finissait par remplacer celui-ci. Or, comme la liste qui suit ne donne que ces *noms de guerre,* sans indiquer les prénoms, il sera parfois difficile d'établir l'identité de ces soldats licenciés au pays. Toutefois, la chose est loin d'être impossible. Beaucoup de ces surnoms ont survécu, et dans la plupart des cas, le nom de famille peut se retrouver assez facilement avec l'aide du dictionnaire Tanguay et des nombreuses études généalogiques publiées depuis. Nous croyons que M. Sulte différera d'opinion avec M. Richard lorsqu'il aura vu cette liste. Constatant la haute valeur de ce "rolle," il reconnaîtra que ces obstacles finiront par s'aplanir et qu'ils seront bientôt surmontés.

M. l'abbé Després a d'ailleurs commencé ce travail, dans son Histoire de la seigneurie de Saint-Ours. Il a trouvé, parmi les premiers habitants de ce fief, un certain nombre de soldats de Carignan, qu'il a reconnus sous leurs "noms de guerre." Le même travail pourrait être fait pour les autres seigneuries et, avec un peu de temps et de patience, toute la liste y passera.

ROLLE DES SOLDATS DU RÉGIMENT DE CARIGNAN-SALIÈRE QUI SE SONT FAITS HABITANS DE CANADA EN 1668

Premièrement de

La Colonelle

Montauban
La Roze
Jolicoeur
Sansoucy
Regnaud
St. Denis
Dufresne
Lafontaine
La Jauge

Saliere

L'Isle d'or
La Lime
Roland
L'Esveillé
Champagne
Courtois
Beausoleil
Belair
La Ramé
Dubuisson
Petit Jean

La Motte St.-Paul

La fleur
Jean de Roy
René
La Vallée
Le Meusnier
Pasquier

Chambly

La Pierre, sergent
Morin
Grandfontaine
Dubuisson, L.
La Jeunesse
Chiron
Jolicoeur
Champagne
La Marche
Le Chevalier
La Roche de Perat
Le Parisien
La fleur

Contrecoeur

Cauder
Des Lauriers
St. Germain
Lapensée
Levallon
La Prairie
La Cave
George d'Ambroise

Grandmaison	La Ramé
Le Boesme	L'Esveillé
Beau Regard	Laforge
La Chapelle	Lachaume
Sansoucy	Champagne
Languedoc	La Jeunesse
	Ladouceur

FROMENT

Desjardins	Rambaux
Sansoucy	La Plante
L'Orange	La Verdure
Francoeur	Jolicoeur
Boutefeu	Monturas
de St. Marc	Marmande
	Quentin dit Pierrot

LAFOUILLE

Le Sr. de Manereuil, enseigne	Beaulieu
Lacroix	La Montagne
La Reverdia	L'Orange
Lafortune	Boutebouilly
St. Germain	Lepetit Breton
desfontaines	St.-Aman
St.-Amand	Lafontaine
Villefaignan	La Pierre
La Charité	Jean Le Niay
La Barre	Laferrière
Germaneau	des Moulins
Maisonseule	Lafontaine Milon
La Tremblade	La Noiray
Du Bois	La Croix
Villefroy	Lafortune
Esmardit	St. Jean
Larivière	La Pensée
Laforest	Le Cardinal

GRANDFONTAINE

Le Sr. de Grandville, enseigne	Le Parisien
La Vigne	La Solay
La Marche	La Tonnelle

Locatte
L'angevin
St. Laurens
La Croix
Lavolonté
Beau Lieu
La fortune
Champagne
Rencontre
Jolicoeur
Bosleduc
La Touche
Le Picart
La flesche
des Moulins
Le Valon
La Touche

Laubia

Le Sr. de Varenne, lieutenant
Le Sr. de Moras, enseigne
La Badie, sergent
La Roze, sergent
La Montagne
La Rigueur
Le Parisien
Le Dragon
La Solaye
La fontaine
La violette
Le Petit la fontaine
Lajeunesse
La Tour
Audouin
La Marche
Sansoucy
des barreaux
du Boulay
des Marchets
La Roye
Le Boulanger
La Rosée
La pensée
Lafleur
Montauban
du Marché

Rougemont

Rencontre
La Rosée

Maximy

Le Sr. du Puis, enseigne
Derussel
Julien
du Mont
Conty
Le Tambour
Le Provençal
La Réthorique
Dampierre
Matta
St.-Martin
Vignaut
Gratte Lart
Jolicoeur
La Verdure
Xaintonge
Beaucourt
Leblanc
La france
Le Merle
Bourjoly
La meslée
La chasse
Belle Isle

LAFREDIÈRE

St.-Antoine
La fleur
Le Limousin
Lagrandeur
La Rousselière
La Bonté
La Verdure
Beaufort
La Rose
L'Espérance
La pensée
La Vergne
La Chaume
Le Parisien
Lafontaine
Le Marcelle
La Barre
Le Major
Delpesches
Belair

LA TOUR

Brisetout
Mabriau
St.-Amour
Maisonblanche
Dupré Rochefort
Martinet
La Rose
Le Breton
Langevin
La Fontaine
La Verdure, sergent
L'Irlande
Champagne
Le Picart

DUGUÉ

La Rivière, sergent
St.-Jean Chastelleraud
Ste-Croix
Bretonniere
Sauvageau
La faveur
La Verdure
L'Espérance
La Marche
La forest

LA VARENNE

La franchise
Ste-Marie
La fleur
Le Chaudillon
Champagne
L'Espérance
La Rivière
La Violette
Barrois
de Moulins
Sallebrune
Petitbois
La Montagne
La Sayette
La Verdure
du Seau
Jolicoeur

PETIT

Boncourage
La Montaigne
La forge
Lafleur
Poitevin
du Verger
de l'Isle
René Le Normand
Le Picart
La violette
Champagne

Saurel

Le Sr. de Saurel, capitaine
Le Sr. Randin, enseigne
La fleur, sergent
Champagne
Le breton
La Pointe
La franchise
du fresne
La france
Grancé
La Violette
Canada
Lafontaine
La Taille
Poitevin
St.-André
St.-Martin
La Roze
La Vigne
La bonté
L'Espérance
Jean Dominique
trempe la crouste
Saluart
Chandillon
La barre
du Vemis
La Chesnaye
St.-Amand
La Porte
La Jeunesse
La Liberté
Le Breton
Olivier

De Porte

Champagne
La Verdure
St.-André
Canadou
Des Jardins
Lagarde
La Noce
La Violette
La Berthe
La Liberté
Amans
Le Petit des Lauriers
d'Ausson
La Pierre

St.-Ours

St. Laurens, sergent
Bavie (Baby) sergent
La Chambre
La Rozée
L'Esveillé
La fontaine
St.-Antoine
St.-Germain
La lande
La guigne
La Croix
Poitevin
La Ramée
La Vigne
La perle
Xainctonge
Jolicoeur
Lafleur
La lime
St.-Martin
Tourangeo
du Villard
Montauban
La Liberté

Le Compte	Jean Bouvet
La fortune	Menarde
des Lauriers	La Fouche
La Vergne	Batanchot
	Le Bruné

NAUROIS

Pierre Morin	Rencontre
Champagne	La Prairie
St.-Surin	Le boesme
Alexandre	Chastelleraud
La fontaine	Le Picart

BERTHIER

La Violette	Lagassé
Petit Bois	Belle Isle
Haudry	La fontaine
le Jeune La Violette	La prairie
La fleur	Champagne
La Verdure	Le Catalan
La Vaux	Jolicoeur
La pensée	Sansoucy
Lamontagne	La Rozée

LA DURANTAYE

La Jeunesse	Mont Rouge
des Lauriers	La Musique

MONTEIL

La Verdure	du four
La Pointe	Grimau
La framboise	La Croix
Vincent	du Bois
Besiers	Villeneuve
La Rivière	La Montagne
La Roche	La Lande
La plante	Bonneau
La fleur	Le Parisien
Sansoucy	Saluer
La jeunesse	Barreau
Berry	Leuradeau
Lafortune	de Bord
L'Espérance	

LA BRISARDIERE

La Combe
Tranchemontagne
Perrier
fayat
La Pierre
Toupin

Total, 403.

Les Ironies de la Mort

Par l'abbé ARTHUR LACASSE

Présenté par l'abbé CAMILLE ROY, M.S.R.C.

(Lu à la réunion de mai 1922)

Fortem virili pectore . . .

I

"Femme, je suis la Mort, et voici le cercueil.
Malgré mon air boudeur, faites—moi bon accueil . . .
Il faut partir, madame! Ôtez, pour ce voyage,
Bagues et bracelets . . . et, sur votre visage
Que, d'une experte main, de blanc mat j'ai fardé,
Laissez tomber ce voile étroit et démodé . . .
Laissez! il n'est plus temps de songer à paraître! . . .
Ce suaire, un passant l'écartera peut-être,
Mais pour ne voir sous ses replis que vos yeux clos . . .
Au pied de votre lit, s'il pleure, ses sanglots
Ne feront tressaillir ni votre âme partie,
Ni votre corps glacé, ni votre coeur sans vie . . .
Devant vous nul blasé ne ploiera les genoux:
Pour tous vous serez morte; ils seront morts pour vous!

"Les fleurs et les parfums dont vous fîtes des pièges,
N'élaboreront plus leurs mortels sortilèges.
Aux regards imprudents fascinés par vos traits,
Une robe modeste a caché vos attraits . . .
Vos mains, hier encor, faciles aux caresses,
Ne s'y prêteront plus, et vos soyeuses tresses
Où scintillaient diamants clairs sertis dans l'or,
Ruissellent maintenant des sueurs de la mort . . .

J'ai dit! vous n'êtes plus; à ma voix tout succombe!
Je garde vos bijoux . . et vous laisse la tombe!"

—La Mort ayant parlé se tut. Et ce fut tout.
Et, devant ce cercueil, je restai là, debout,

Méditant, effrayé, les leçons de l'abîme . . .
. . . .
Vanités! vanités! que le vain monde estime,
Dites, qu'apportez-vous à vos adorateurs,
Que remords impuissants et que rêves menteurs!

Femme mondaine, qu'as-tu fait de tes tendresses,
De ta beauté, de ton esprit, de tes richesses?
O reine des salons et des bals enivrants,
Si tu fus mère, qu'as-tu fait de tes enfants?
De tes enfants si purs et si beaux dans leurs langes,
Que Dieu t'avait donnés pour en faire des anges,
Toi qui ne sus offrir à leurs yeux large ouverts
Que le spectacle vain de ce monde pervers!
Qui, rebelle à la voix de l'Eglise et du prêtre,
Ne rêvant que plaisirs, jamais n'as su connaître
L'amour du sacrifice et des saints abandons!

As-tu goûté, du moins, la douceur des pardons
Et des relèvements après la chute, ô femme? . . .
Hélas! . . . dis-moi, dis-moi, qu'as-tu fait de ton ame! . . .
. . . .
Silence de la tombe! O jour terrible! O deuil!

Et, lorsqu'elle t'a prise et jetée au cercueil,
Le Mort t'a-t-elle au moins, femme trop adulée,
Laissé des courtisans qui t'auraient consolée? . . .
Las! dans le salon vide aux grands lustres éteints,
Même leur souvenir se fait déjà lointain! . . .

II

Ah! bienheureuse l'âme habituée aux cimes,
L'âme aux pensers féconds, aux dévouements sublimes,
Forte contre l'attrait du monde et de son or,
Qui travaille à son ciel en songeant à la mort!
Bienheureuse la femme au coeur pur et fidèle,
Pour qui modes et bals ne sont que bagatelles,
Et dont le regard clair toujours levé vers Dieu,
A tous ces faux brillants préfère le ciel bleu;
Qui, jusques en ses deuils conservant son sourire,
Comme on court au festin, marcherait au martyre;

Qui sait s'agenouiller, et sait rester debout;
A qui suffit sa tâche, et qui suffit a tout!
. . . .

Femmes à l'oeil modeste, aux mains laborieuses,
Ayant le front pudique et les lèvres rieuses,
Conseillères de l'homme et reines du foyer;
Aptes à commander, capables de prier,
Puisant votre heroïsme au Coeur de l'espérance,
Vous n'avez jamais fui ni labeur ni souffrance;
Plus fières de vêtir le pauvre d'un manteau,
Que de gloser, tricorne au front, sur un tréteau;
Vous avez mieux aimé qu'un triomphe éphémère
Le silence fécond de vos foyers, ô mères,
Et vous ne songez pas qu'on puisse, en sa maison,
Se trouver à l'étroit comme en une prison! . . .
Car ce modeste toit—ô l'étonnant spectacle!—
Est devenu, par vous, un riant tabernacle,
Un autre Nazareth embelli par l'amour,
Que la Sainte-Famille a choisi pour séjour! . . .

Sans dédaigner, pourtant, le soin d'être agréables,
Vous avez le souci de rester vénérables!
Tel un joyau de prix jalousement porté,
La pudeur fait plus grande encor votre beauté.
Vous n'etes pas l'esclave abject qui s'accommode
De l'esthétique chère aux inventeurs de modes.
Travaillant tout le jour, vous reposant le soir,
Vous êtes devant Dieu des femmes de devoir! . . .

Aussi la Mort, pour vous, taira ses ironies,
Et vous prenant avec respect, femmes bénies,
Ne fera qu'ajouter à votre front si beau,
La majesté profonde et douce du tombeau!

(D'un volume en préparation.)

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SECTION II

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PRESIDENTIAL ADDRESS

Upper Canada a Century Ago

By THE HONOURABLE WILLIAM RENWICK RIDDELL, LL.D., F.R.S.C., ETC.

(Read May Meeting, 1922)

It will not seem inappropriate that I should address a Section of a Canadian Society devoted, *inter alia*, to History, upon the state a hundred years ago of one Province—now a Province of the Dominion of Canada—and it is natural that I should select my own Province, then called Upper Canada.

Upper Canada came into existence, technically, by the Order-in-Council at the Court of St. James's, August 24, 1791, whereby the Province of Quebec was "divided into two distinct Provinces to be called the Province of Upper Canada and the Province of Lower Canada." [1] But the government of the new Provinces was provided for by the Canada or Constitutional Act (1791), 31 George III, c. 31 (Imp.), which was brought into force, Monday, December 26, 1791, by the Proclamation of General Alured Clarke of November 18, 1791.[2]

The Province of Upper Canada had as its eastern limit a line beginning at a stone boundary on the north bank of the Lake St.

[1] "Documents Relating to the Constitutional History of Canada, 1791-1818." Doughty and McArthur, Ottawa, 1914, pp. 1-3; 4 Ont. Arch. Rep. (1906), pp. 158-160.

[2] The Canada Act (1791), 31 George III, c. 31 (Imp.), s. 48, provided that the King might fix or authorize the Governor or Lieutenant-Governor of the Province of Quebec or the Administrator of the Government there to fix the day for the commencement of the Act. The Order-in-Council of August 24, 1791, ordered Henry Dundas (afterwards Lord Melville), Secretary of State for the Home Department (which was charged with the care of the colonies, 1782 to 1801), to prepare a warrant for the Royal Sign Manual authorizing the Governor, Lieutenant-Governor or Administrator of the Province of Quebec to fix the day not later than December 31, 1791. The warrant issued: Lord Dorchester, the Governor of the Province of Quebec, was still in England, and Alured Clarke, the Lieutenant-Governor, fixed the day by his Proclamation. For this Proclamation see D. & McA., pp. 55-57; 4 Ont. Arch. Rep. (1906), pp. 169-171.

Francis, at the Cove west of Pointe au Bodet and running northerly in a defined direction until it struck the boundary line of Hudson Bay, "including all the territory to the westward and southward . . . to the utmost extent of the country commonly called or known by the name of Canada." [3]

It had been found impossible to follow the description of the eastern boundary exactly, but the Surveyor-General drew a satisfactory line[4]—there was no need to be particular about the northern boundary, settlement had not gone so far in that direction. Toward the United States, to the west and south, the boundary had been defined by the Definitive Treaty of Paris, 1783, the middle line of the St. Lawrence, the Great Lakes and their connecting rivers.[5] While part of the *de jure* territory of the United States had been detained for a time by Britain and was *de facto* part of Upper Canada, it had all been given up in 1796 under the provisions of Jay's Treaty, 1794.[6]

The precise line had not been fixed in certain places one hundred years ago. There was a dispute as to the international line; and by the Treaty of Ghent, December 24, 1814, the matter was agreed to be referred to two Commissioners, one on each side.[7]

The first British Commissioner was John Ogilvy of Montreal, but he died at Amherstburg in 1819 of fever caught in the swamps of

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[3]There is a misprint of the word "of" for "on" in the copy in 4 Ont. Arch. Rep. (1906), p. 159—the original capitalization has not been followed in this copy.

[4]See the note on the map opposite D. & McA., p. 72—the mistake was in the Order-in-Council.

[5]This Treaty is given in "Documents Relating to the Constitutional History of Canada, 1759-1791," edited by Shortt and Doughty, 2nd edit., Ottawa, 1918, pp. 726-730. "Treaties and Conventions, United States, etc." Washington, 1889, pp. 375-379.

The statement in the text as to the northern boundary is not exactly correct—already there was a desire for a port on Hudson Bay. See Baldwin's Motion in the Assembly, December 29, 1823, 10 Ont. Arch. Rep. (1913), pp. 564, 589. I have shortened the description of the treaty boundary between Canada and the United States.

[6]The border ports of Michillimacinack, Detroit, Niagara, Oswego, Oswegatchie, Point au Fer, Dutchman's Point, were held by Britain because the United States had not implemented their agreement that the British creditors should find no lawful impediment to the recovery in full of their claims on American debtors. Washington, April 16, 1794, sent John Jay, Chief Justice of the United States, to England and he, November 19, 1784, secured a treaty whereby the United States were to pay the retained debts and Britain to give up the retained territory. Britain gave up the territory in 1796 and the United States paid £600,000 in 1802.

Jay's Treaty will be found in "Treaties and Conventions, etc.," pp. 379-395.

[7]The Treaty of Ghent, "Treaties and Conventions, etc.," pp. 399-405.

St. Clair and was succeeded by Anthony Barclay of Nova Scotia. The American Commissioner was General Peter Buel Porter of Niagara, who had made a good record as a soldier in the war of 1812-14 and was later to be Secretary for War in Adams' Cabinet. They made an award at Utica, June 18, 1822, which was carried into effect.

The Commissioners had not agreed; but the British Government gave Barclay specific instructions to give up to the United States Sugar, Fox and Stony Islands in the Detroit River as the price of an immediate amicable determination of the boundary under the Treaty of Ghent—the United States giving up all claim to Bois Blanc.[8]

The Utica Award settled all difficulty as to the United States boundary to the Neebish Channel; and the Convention of October 20, 1818, fixed a line from the most northwestern point of the Lake of the Woods to the 49th Parallel, N.L. The Ashburton Treaty of 1842 fixed the line from the Neebish Channel to the most northwestern point of the Lake of the Woods.

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[8]See letter Anthony Barclay to Sir Peregrine Maitland, Lieutenant-Governor of Upper Canada, dated from Utica, June 21, 1822, Can. Arch. Sundries, U.C., 1822.

The Utica Award, "Treaties and Conventions, etc.," pp. 407-409.

It is foreign to my subject to more than refer to the dismay and resentment of many in the Province at the Award to the United States of Barnhart's Island, near Cornwall, now part of Massena Township in St. Lawrence County, New York. The Legislature of Upper Canada made a strong representation to the Crown expressing inability to conceive on what grounds a boundary was assented to which gave to the United States "the only deep and safe channel" and asserting that it was "wholly impracticable for rafts of timber, staves and other lumber, which are among the principal exports of Upper Canada, to descend to the only market . . . open to them by the shallow, dangerous and intricate channel on the north side of Barnhart's Island."

The matter came up very frequently in the House during 1823 and 1824—see 11, Ont. Arch. Rep. (1914), pp. 269, 272, 274, 275, 276, 280, 458, 472 (where Barnhart's Island is first specifically mentioned, November 27, 1823), 473, 474, 476, 480 (an answer by the Lieutenant-Governor that that part of the boundary had undergone a careful survey and examination by the Commissioner of the Navy, who had made a Report to the Secretary of State for the Colonies, December 1, 1823), 538, 614, 615 (Resolutions of Assembly, January 6, 1824), 623, 624, 666, 667 (Address to the Lieutenant-Governor, January 16, 1824), 674, 676 (Address to the King, January 17, 1824), 683.

In the Legislative Council, 12 Ont. Arch. Rep. (1915), pp. 240, 241, 245, 247, 262, 265, 266, 271, 278, 279, 280. (The indexing to these volumes is very unreliable, being the only serious defect in this otherwise admirable series.)

The Ashburton Treaty of 1842 by Article VII made the channels on both sides of Barnhart and Long Sault Islands open to ships, etc., of both parties. "Treaties and Conventions, U.S., etc.," pp. 432 *sqq*.

The western boundary of the Province was still uncertain; claims were made that Upper Canada extended to the Rocky Mountains and also that it extended not quite to the head of Lake Superior—this boundary was finally settled in its present position in 1889 by the Act 52, 53 Vict., c. 28 (Imp.).[9]

Districts

The judicial and administrative unit was still the District; there were, indeed, Counties, but these were practically but convenient names for certain portions of territory. Townships had an embryo municipal system, but the District was the important matter. Each District had its District Court with jurisdiction in contract from 40 shillings to £15 (in liquidated claims to £40), and in tort to personal chattels to £15. It had its Court of Quarter Sessions for criminal cases, its Sheriff, Constables, etc. The Court of Quarter Sessions levied the taxes, laid out roads, etc.—and it was the real municipal authority.[10]

The Lieutenant-Governor was Sir Peregrine Maitland; he had shaken off the influence of Chief Justice William Dummer Powell;

[9]The Quebec Act (1774), 14 George III, c. 83, extended the Province of Quebec to the Ohio River down to "the banks of the Mississippi and northward to the southern boundary of the territory granted to the Hudson's Bay Company."

The true boundary of Upper Canada depended on the meaning of the word "northward," Sir John A. Macdonald, in the historic controversy with Sir Oliver Mowat, claiming that it meant "due north," Sir Oliver that it meant "northerly along the banks of the Mississippi." In the event, the latter interpretation prevailed in the Judicial Committee, 1884, as it had with the arbitrators, Chief Justice Harrison, Sir Francis Hincks and Sir Edward Thornton, 1878, whose unanimous award Sir John refused to accept. The decision of the Judicial Committee, August 11, 1884, was carried into legal effect by the Imperial Act of 1889.

[10]For the District Court see the Act (1822), 2 George IV, c. 2 (U.C.); for the assessment, etc. (1819), 59 George III, c. 7 (U.C.). Under 15/ was sued for in the Court of Requests presided over by Justices of the Peace—this became the Division Court in 1841, 4, 5 Vict., c. 3 (U.C.). The Districts were abolished in 1849 by the Act 12 Vict., c. 78 (Can.), and the County became the judicial unit, District Courts becoming County Courts.

The Districts in existence in 1822 were:

1. Eastern, created as District of Luneburgh by Lord Dorchester's Proclamation of July 24, 1788; name changed by Act (1792), 32 George III, c. 8 (U.C.).
2. Midland, Mecklenburgh by same Proclamation and name changed by same Act.
3. Home, Nassau by same Proclamation and changed by same Act.
4. Western, Hesse by same Proclamation and changed by same Act.
5. Johnstown, formed 1798, 38 George III, c. 5.
6. Niagara, formed 1798, 38 George III, c. 5.

John Beverley Robinson, the able Attorney-General, had now more influence with him—by no means so great as was generally supposed, however.

Already there were movements looking towards responsible government; the Legislature had in 1816 voted £2,500 towards the expense of the administration of the civil government of the Province:[11] and this entitled the people's representatives to a say in who should spend it. But nothing seemed further from the official mind than this; and the Executive Council was still responsible to the "Crown" alone. The Eighth Parliament was sitting. The Legislative Council was nominated; as in the case of the members of the Executive Council, a mandamus was issued by the Home Administration, and the nominee was entitled to be sworn in. In the Legislative Council the practice was that the Chief Justice was the Speaker; and Powell was the incumbent from before his appointment as Chief Justice in 1816 until he retired in 1825.[12]

In the Legislative Assembly every county with a population of 1,000 had one member, those with a population of 4,000, two each, the representation of no county to be reduced, and every town in which the Quarter Sessions sat had one member—41 members in all.[13]

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7. London, formed 1798, 38 George III, c. 5.
8. Newcastle, authorized by same Act, formed *de facto*, 1802.
9. Ottawa, formed 1816, 56 George III, c. 2.
10. Gore, formed 1816, 56 George III, c. 14.

(Provision was made (1821), 2 George IV, c. 3, for the Counties of Carleton and Simcoe to be proclaimed Districts.)

[11]The Statute granting this money is (1816) 56 George III, c. 26 (U.C.); it has not, *me judice*, received the attention which it deserves. Before 1816, the Mother Country paid the whole expense of the civil administration of the Province and it would have been illogical for Canadians to ask to dictate who should spend the money. The opposition of Weeks, Willcocks, Thorpe, etc., in 1806 seems to have been simply factious.

[12]In addition to the (1) Speaker there were present during the Session of 1821-22:

2. James Baby.
3. John McGill.
4. Thomas Scott (former C.J.).
5. William Claus.
6. William Dickson.
7. Revd. John Strachan.
8. Angus McIntosh.
9. Joseph Weeks.
10. Duncan Cameron.
11. George H. Markland.

(They were paid £100 a year except when they were Honorary members.)

[13]This was provided by the Act (1820), 60 George III, c. 2. (U.C.).

The following counties had at least two members:

(*a*)	Glengarry:	1. Alexander Macdonell, York.
		2. Alexander McMartin, Cornwall.
(*b*)	Prescott & Russell:	3. William Hamilton.
		4. David Pattie, Hawkesbury.
(*c*)	Stormont:	5. Archibald McLean, Cornwall.
		6. Philip Van Koughnet, Cornwall.
(*d*)	Grenville:	7. Walter F. Gates, Johnstown.
		8. Jonas Jones, Brockville.
(*e*)	Leeds:	9. Levius P. Sherwood, Brockville (Speaker).
		10. Charles Jones, Brockville.
(*f*)	Lennox and Addington	11. Samuel Casey, Adolphustown.
		12. Barnabas Bidwell, Kingston.
(*g*)	Prince Edward:	13. James Wilson, Picton.
		14. Paul Peterson, Hallowell.
(*h*)	Northumberland:	15. David McGregor Rogers, Haldimand.
		16. Henry Ruttan, Haldimand.
(*i*)	York & Simcoe:	17. Peter Robinson, York.
		18. William W. Baldwin, Spadina.
(*k*)	Wentworth:	19. George Hamilton, Hamilton.
		20. John Willson, Saltfleet.
(*l*)	Halton:	21. James Crooks, Dundas.
		22. William Chisholm, Nelson.
(*m*)	Lincoln:	
	1st Riding:	23. John Clarke, St. Catharines.
	2nd Riding:	24. William J. Kerr, Waterford.
	3rd Riding:	25. Robert Hamilton, Queenston.
	4th Riding:	26. Robert Randall, Queenston.
(*n*)	Middlesex:	27. Mahlon Burwell, Port Talbot.
		28. John Bostwick, Talbot Settlement.
(*o*)	Norfolk:	29. Robert Nichol, Stamford.
		30. Frances Legh Walsh, Vittoria.
(*p*)	Essex:	31. Francis Baby, Sandwich.
		32. William McCormick, Amherstburgh.

The following counties had one member each:

(*q*)	Dundas:	33. Peter Shaver, Matilda.
(*r*)	Frontenac:	34. Allan McLean, Kingston.
(*s*)	Carleton:	35. William Morris, Perth.
(*t*)	Hastings:	36. Reuben White, Belleville.
(*u*)	Durham:	37. Samuel Street Wilmot, Clarke.
(*v*)	Oxford:	38. Thomas Horner, Burford.
(*w*)	Kent:	39. James Gordon, Amherstburgh.

And the towns with one member each:

(*x*)	Kingston:	40. Christopher Alexander Hagerman, Kingston.
(*y*)	York:	41. John Beverley Robinson, York.

One of the most interesting episodes in our parliamentary history occurred in this Parliament.

Barnabas Bidwell, who had been Attorney-General of Massachusetts, 1807-1810, and a member of Congress, fled to Upper Canada in 1812, having been charged with embezzlement. He was elected as a member of the Legislative Assembly for Lennox and Addington at a by-election, November 5, 1821; petitioned against as an alien, he was unseated by the House, January 4, 1822; at the election ordered, the Returning Officer refused to accept the nomination of Marshall Spring Bidwell, his son; and of the two other candidates, Matthew Clark and Thomas Williams, the former was elected, February, 1822. Clark was unseated, February 14, 1823, and at the new election Marshall Spring Bidwell and George Ham were the candidates. Ham was declared elected on a poll 518 to 505, but was unseated on petition, December 8, 1823. A new election was ordered by the House, but the Parliament was dissolved. At the ensuing general election in 1824, Marshall Spring Bidwell was returned a member for this constituency along with Peter Perry, another advocate of responsible government.

The right of immigrants from the United States to vote and to be Members of the House was a burning question which agitated the Province for years; it resulted in the Act of (1824) 4 George IV, c. 3 (U.C.), which effectually excluded such as Barnabas Bidwell, but qualified his son.[14]

Another matter which caused the Legislature much concern was the difficulty with Lower Canada over the proportion of duties to be paid by that Province to Upper Canada.

Practically all the goods imported into Upper Canada from the British Isles came up the St. Lawrence and Lower Canada levied a tariff upon such goods; and an arrangement was entered into through Commissioners appointed by the Governors (see the Upper Canada Act (1793), 33 George III, c. 9), whereby Upper Canada refrained from imposing duties upon goods coming through Lower Canada and the two Provinces divided the duties levied by Lower Canada. Commissioners were appointed in 1793, 1796, 1801, 1804, etc., down to 1817—when the arrangement made by the last-mentioned Commissioners expired in 1819 a very considerable agitation arose between the Provinces. Lower Canada kept all the money.

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[14]The subsequent career of Marshall Spring Bidwell is too well known to call for comment here. The facts concerning the elections, etc., will be found set out in 10 Ont. Arch. Rep. (1913)—Kingsford's account is inaccurate.

I have discussed this matter somewhat fully in my article, "The Tragedy of the Bidwells."

Early in 1821, Sir Peregrine Maitland drew the attention of Parliament to the matter and it was carefully considered. A Joint Committee of both Houses made an elaborate report, December 22, 1821, setting out in detail the history and the difficulties which had arisen, and recommended that "A person of talent and respectability sufficient to solicit and represent the interests of this Province should be commissioned to present the Address at the foot of the Throne." Chief Justice Powell expected to be appointed and had been spoken to by the Lieutenant-Governor in that sense, but both Houses united in an Address to Sir Peregrine Maitland asking him to appoint John Beverley Robinson, the Attorney-General, who had had general charge of the matter for the House and who probably knew more about it than any one else. Robinson was appointed, to Powell's dismay and indignation, and this put an end to the lifelong personal friendship of these two eminent men.[15]

When Robinson was in England he combated the scheme which had been decided upon by the Home Administration for the Union of the two Canadas: in this he did not act officially but expressed his own views. Opinion was divided in the Province as to the merits of the proposition: it would not be very far from literal fact to say that, on the whole, the Liberals were in favour and the Tories adverse. However that may be, the House, by a vote of 18 to 15, resolved that the representatives did not feel themselves competent to speak on such an important matter for their constituents, as the proposed change had not been contemplated at the time of the election: a subsequent motion to expunge was lost on a vote of 4 to 18.

The Legislative Council passed an Address to His Majesty confessing their "inability to decide upon the general policy of the measure." [16]

The very strongest opposition was manifested in Lower Canada, and the Bill was allowed to drop—the matter not to be seriously taken up again till after Lord Durham's Report.

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[15]See this Report in 11 Ont. Arch. Rep. (1914), pp. 97-115. Address for the appointment of Robinson, 11 Ont. Arch. Rep. (1914), pp. 164, 176. For the quarrel see the Powell MSS. and many letters of Robinson, Strachan and others in the Can. Arch. Sundries, U.C., 1822. Powell shows up very badly in this matter—*ira furor brevis*—apparently his usual robust common sense failed him, and indeed a general failing of his faculties is noticeable at this time. *Valde deflendus.*

[16]The Draft Bill will be found 11 Ont. Arch. Rep. (1914), pp. 237-243. The proceedings in the House are in 11 Ont. Arch. Rep. (1914), pp. 300, 303, 304, 310, 311, 318, 322 (Resolution), 342 (Motion to expunge); in the Council, 12 Ont. Arch. Rep. (1915), pp. 145, 146 (the Address).

The most interesting, if not the most valuable, documents concerning Upper Canada a century ago, are to be found among the Sundries, U.C., in the Canadian Archives; and I shall devote the remainder of this paper to what is either expressed in these documents or is indicated or suggested by them.

The reports of the judges to the Lieutenant-Governor throw a lurid light on the brutality of the criminal law, but at the same time often indicate the means taken to mitigate its rigours.

Mr. Justice Campbell took the Home Circuit at Hamilton[17] (now Cobourg) for the District of Newcastle, September 18. At the Newcastle Assizes was tried an Indian lad, Negaunausing, ten years old, who had shot "a European boy, John Donaldson, of nearly the same age." He was a bright and intelligent lad; he quite understood what he was doing and his nonage did not save him from conviction for *Malitia supplet aetatem*. He was sentenced to death.

Mr. Justice Campbell made a formal report. The case of the young Indian was taken up by Charles Fothergill of Rice Lake and Port Hope,[18] and the matter again submitted to the trial judge for his opinion. He advised clemency: although the boy undoubtedly understood the act and intended the result, there were three reasons for mercy—his youth, his ignorance of the consequences to himself of the crime, and the absence of any previous quarrel or illwill.

[17]Called after the township in which it is situated. For some time after the foundation of the present city of Hamilton there was a distinction made between Hamilton and Hamilton in the Gore District. The name Cobourg was well established by 1821 when the Sheriff received a charter for a fair "in the town of Cobourg in the Township of Hamilton," August 2.

For a provision for sale of the old site after construction of the new Court House see the Statute (1836), 6 Wm. IV, c. 23 (U.C.); but that is another story.

[18]Charles Fothergill, J.P., was an Englishman of superior education; he had an elegant cottage at Port Hope and a residence on Rice Lake. He spoke against Robert Gourlay at the memorable meeting of the inhabitants of the Township of Hope and Hamilton in 1818 which ended Gourlay's hope of success in the District of Newcastle. He became King's Printer in 1821, published the *Gazette* and the *York Almanac*. He, however, lost that situation in 1826 on account of his conduct in the House of Assembly in which he was member for Durham. He was an accomplished naturalist and wrote several volumes of manuscript on the animals and birds of the continent. He supplied the celebrated artist, Bewick, with a horned owl stuffed for illustration, and took an active part in an abortive scheme for a Museum and Institute of Natural History and Philosophy with Botanical and Zoological Gardens attached at York (Toronto). See my "Life of Robert (Fleming) Gourlay," Ont. Hist. Soc. Papers and Records, vol. 14 (1916), pp. 37, 60.

The Indian name "Ganaraska" was replaced by "Smith's Creek" from the mill stream at whose mouth it was built—as Cobourg, seven miles east, was sometimes known as Perry's Creek—the village Ganaraska had the name Toronto for a short time, but when made a Port of Entry the permanent name Port Hope (from the township in which it was situated) replaced all others (1820-21).

It was nearly a year before the pardon was decided upon, and the boy lay in gaol at Cobourg. When the pardon was granted it was on condition that the chiefs of the tribe to which he belonged should give security that he would banish himself from Upper Canada for life. On this being transmitted to the Sheriff of the Newcastle District, John Spencer, he was in a quandary as to the form the security should take and wrote to Major Hillier.[19] How the matter was arranged does not appear, but it is quite certain that the boy was not hanged.[20]

John Brown, lying in the gaol at York sentenced to death for stealing, is "unprepared to meet his Almighty Maker" and petitions for a commutation.[21] Denis Sullivan, a lad of 17 recently arrived from Ireland, lay in Cornwall Gaol sentenced to death for horse stealing, but is pardoned on condition of banishing himself for life—indeed John Beverley Robinson, when the question was raised during the Willis controversy, was able to say that in his time in office, going back to 1812, there had been no executions for simple horse stealing.[22] Philip Matheson, in the Johnstown District Gaol at Brockville sentenced to death for the same offence, also found mercy.[23]

The escape of prisoners from the district gaols was very common, just as it has been 100 years later in this Province—to the indignation of law-abiding citizens.

The pillory was still in common use, and whipping was an ordinary punishment for theft not punishable with death.

Riding on a rail a man who is *persona non grata* to his neighbours, the courts refused to look upon as a mere bit of fun; the perpetrators were imprisoned for a considerable time and found no mercy.

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[19]The letter is dated Hamilton, 26th October, 1821, Can. Archives Sundries, U.C., 1821. Several writers have been misled by want of caution in distinguishing the two Hamiltons.

[20]It is one of my earliest recollections seeing the crowd of people around Cobourg Gaol at the "Court House" (formerly Amherst village) on the hill at the north of the town to witness the execution of Dr. King for the murder of his wife by arsenical poisoning. The trees giving on the gaol yard were crowded with men. This was the first (and only) execution at Cobourg.

The Indian was possibly of the Mississaugua Band of the Bay of Quinte who a few years later were settled in the Township of Alnwick—Chippewas they are sometimes called—or he may have been one of the "Rice Lake Band," what is now the Hiawatha Band on the north shore of Rice Lake.

[21]Letter, April 3, 1822.

[22]Petition, September 6, 1822; see papers printed by order of the (Imperial) House of Commons relating to the removal of Mr. Justice Willis.

[23]Petition, September 9, 1822.

Illegal celebration of marriage got many ministers and elders into trouble; the Church of England was tenacious of its valuable privileges.

The claim recently advanced that the Indians on the Grand River Reserve were allies and not subjects of the King makes its appearance and is disposed of adversely to the Indians.[24]

Leaving the criminal law, we find many reminders of the War of 1812.

Mary Livingston, of the District of Niagara, is the widow of Peter Lee, who was a private soldier in the Coloured Corps raised by Captain Robert Ranchey. He was injured in the war and died of the injury. She asks for a pension and is granted it.[25]

Richard Pierpont, "a man of colour, a native of Africa and an inhabitant of the Province since the year 1780," petitions Sir Peregrine Maitland, setting out that he was a native of Bondon in Africa; at the age of 16 he was made a prisoner and sold as a slave; sent to America and sold to a British Officer, he fought through the Revolutionary Wars on the side of the Crown in Butler's Rangers, and also fought through the War of 1812 in the Coloured Corps raised at Niagara. He is old and poor and asks relief by being furnished means to go to England and thence to a settlement near the Gambia or the Senegal Rivers, from which he could return to Bondon, or "in any manner Your Excellency may be graciously pleased to order." It does not appear what disposition was made of this petition, but as "Captain Dick" is vouched for by Adjutant-General Coffin, it may be taken for granted that he obtained relief.[26]

Certain Indian land on the Grand River had been leased for a long term to Benajah Mallory, Member of the House of Assembly for Oxford and Middlesex in the Fifth Parliament, 1808-1812. Mallory proved himself a traitor and joined the enemy in the War of 1812. His land was forfeited and, after inquest found, was sold to Mr. Sheldon. But it was claimed by William Johnson Kerr for the heirs of Elizabeth Kerr, wife of Dr. Kerr and daughter of Molly Brant (William Johnson Kerr himself married Elizabeth, daughter of Joseph Brant). Augustus Jones, the Surveyor who married an Indian woman, swore that the land had been given to Dr. Kerr's family by

[24]See my judgment in the recent case, Sero *v.* Gault (1921) 50 Ontario Law Reports, 27; the opinion of John Beverley Robinson, Attorney General of Upper Canada cited therein; also the case of The King *v.* Esther Phelps (1823), Taylor's K.B. Report, U.C. 47, and the argument of Henry John Boulton, Solicitor-General for Upper Canada, afterwards Chief Justice of Newfoundland, at pp. 53, 54.

[25]See petition and endorsement, March 1, 1822.

[26]Petition and endorsement, July 21, 1821.

the Six Nation Indians in 1795 or 1796 agreeable to the wishes of Captain Joseph Brant and the other Indian Chiefs, and William K. Smith corroborates Jones—a whole aboriginal romance involving Sir William Johnson's morganatic marriage, the wonderful Miss Molly and her charming daughters, the grant to the Indians by Sir Frederick Haldimand, their generosity, the war, the treason, the forfeiture.[27]

The unhappy results of mingling with the whites are illustrated by the report of William Macaulay to Major Hillier, the Governor's Secretary, from Cobourg, November 25, 1822, telling of the communication of small-pox by a family of immigrants at Port Hope to the Indians who inhabit in the vicinity of Rice Lake," and though Dr. Gilchrist has, with great humanity, vaccinated some . . . it is to be feared that the contagion will spread." Spread it did and decimated the unfortunate tribe.[28]

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[27]March, May and August, 1822.

[28]Dr. Gilchrist was Dr. John Gilchrist, one of a family of physicians familiarly and affectionately known by their Christian name. He was "Dr. John," born at Bedford, N.H., he was educated at New Haven, Connecticut, and secured his diploma from Yale University. He was the first to receive a certificate of qualification to practise Physic Midwifery and Surgery from the Upper Canada Medical Board created under the Act (1818), 5 George III, c. 13 (U.C.), being composed of Drs. James Macaulay, Christopher Widmer, William Lyons, Grant Powell and William Warren Baldwin.

The four first named held their first meeting at York, January 4, 1819, and examined two candidates. "Mr. John Gilchrist, of the Township of Hamilton, in the district of New Castle, appeared and being examined and found duly qualified to practise Physic Midwifery and Surgery; he received a certificate to that effect accordingly.

Mr. John S. Thomas of Markham, in the Home District, likewise appeared and on examination was found totally unqualified to practise in either branch."

The Board received for every certificate the sum of £3 10s. ($14) from the successful candidate, who then took the certificate to the Private Secretary of the Lieutenant-Governor, and upon paying the Secretary 20s. ($4) he received a licence to practise.

Dr. "John" practised near Cobourg; in 1822 he became surgeon to the 1st Northumberland Regiment of Militia. Later he removed to Otonabee and founded the village of Keene, where he erected saw and grist mills—in 1831 he went back to practice in Cobourg; removing to Peterborough he became member of the Legislative Assembly in the new Province of Canada. He was arrested as a rebel in 1838 but released. In 1849 he removed to Port Hope, where he died in 1859.

Of the other Gilchrists, "Dr. Sam" and "Dr. Matthew" of New Castle District received their certificate, January 1824; and James Eikin Gilchrist of New Castle, "Dr. Jim", his January, 1832. I knew "Dr. Jim" in Cobourg half a century ago, still practising; he had been educated at Dartmouth College, N.H., from which he received the degree of M.D. "Dr. Hiram" also received the degree of M.D. from Dartmouth; he failed before the Board, April, 1834, in Latin. All these, except Matthew, were brothers.

Duelling was not extinct—Anthony Marshall, J.P., of Kingston, complains to Maitland of Captain Raines, commanding a troop of Militia Cavalry (Dragoons), abusing him for certain acts done as a magistrate, and sending him a challenge by Mr. Innes, Wednesday, October 24, 1822. Marshall at once referred him to Mr. Robert Stanton. The next day there was a notice put up in the Post Office signed "Fras. Raines," declaring Mr. Marshall to be "no Gentleman and a Coward," also on two posts of the Marketplace "a creamer" posted:

"Kingston, 23 Oct., 1822.

"I do hereby declare Mr. Marshall, of Kingston, Surgeon, etc., to be no Gentleman and a Coward.

"Fras. Raines."[29]

The feud between Lord Selkirk and the North-Western Company had left its traces.

The District of Ottawa, recently formed by the Act (1816), 56 George III, c. 2, of the Counties of Prescott and Russell, which were detached from the Eastern District, had required a Sheriff, and Alexander Macdonell wished to be appointed. He was unsuccessful in his application because he was under indictment in connection with the Selkirk-N.W. Co. troubles. He applied, without success, to be tried; and finally the indictments (in Lower Canada) were *nolle prosequied.* Simon McGillivray, now at Port Talbot, writes Mayor Hillier, Maitland's Secretary, on behalf of Macdonell. On his return to Montreal McGillivray writes again, October 12, 1822, with certificates of quashing indictments against Macdonell. In this letter are certain statements worth copying in full. McGillivray says that, on looking over the indictments and the persons against whom they were found, "I am forcibly reminded of a conversation which I had, or rather a series of remarks to which I listened, on a certain occasion five years ago from a magistrate who had been much occupied in taking the affidavits of Lord Selkirk's witnesses and whose professional caution was at the time rather diminished by a social glass. He began

[29]It appears that Lieutenant Innes appeared before Pringle, J.P., and Marshall, J.P., and that Marshall forgot himself for a moment and said that Raines "told a story"—he denies that he used the shorter and uglier word "lied." Raines called him rascal, villain, coward and other like terms, and the same day sent him two challenges through Innes.

Is "creamer" intended for "screamer"? The lexicographers do not know the word.

by paying me compliments, the tendency of which I was at a loss to understand until at last he said: 'I am sorry for your fate, for with all this you will certainly be hanged.' And on my requesting an explanation he proceeded: 'Why, man, you have to deal with a man of the most formidable controversial powers of this or perhaps any other age, and his interest requires that you should be disposed of. By controversial powers, Sir'—my friend was fond of definitions—'I mean the power of proving anything a man chooses, and I believe Lord S.'s powers in that way to be so great that he might even succeed in burning a Cardinal. Perhaps, Sir, you do not know for what cause a Cardinal may be burnt. A Cardinal may be burnt for either of two crimes, Heresy or Adultery. Now as heresy is a sort of hypothetical crime of which the proof is rather difficult, and of which other Cardinals are to be the Judges, it is not likely that a Cardinal should ever be burnt for heresy—but adultery is a matter that may be proved by direct testimony, and to convict a Cardinal it requires seventy-two eye-witnesses of the fact. Now, Sir, my Lord Selkirk shall turn you out seventy-five.'"

The New England theologian, Noah Worcester, who had been a soldier in his youth and who took an active part in the Massachusetts Peace Society founded after the close of the War of 1812, and himself wrote practically all the contents of the quarterly, "The Friend of Peace" (1819-1828), wrote, September 11, 1821, from Brighton, Mass. (where he had settled in 1813), to Sir Peregrine Maitland inviting his attention to the objects of his Society "to prevent another war between Great Britain and the United States."

The navigation of Rice Lake and the River Trent, "85 miles from the head of Rice Lake to the Bay of Quinté," was urged upon the Governor as of great importance.[30]

In legal circles there was still an occasional echo of the unsuccessful attempt of Christopher Alexander Hagerman in 1815 to obtain the distinction of King's Counsel. Sir Frederick Phipse Robinson had passed his appointment and it was duly gazetted; but before the patent could issue, Robinson had lost the position of Administrator of the Government and Gore had returned as Lieutenant-Governor. Gore submitted the matter to the Judges, they reported against the patent and no King's Counsel were in fact appointed until 1838.[31] In 1822 Mr. Justice Campbell, one of the Judges who reported against the project, writing to Major Hillier recommending Mr. (afterwards

[30]Letter from Charles Hayes, October 31, 1821.

[31]See my article, "The First and Futile Attempt to Create a King's Counsel in Upper Canada," in 40 Canada Law Times (February, 1920), pp. 92, *sqq*.

Chief Justice, Sir) James Buchanan Macaulay as Crown Prosecutor on the Western Circuit, after saying that such appointments are not made by seniority at the Bar, adds: "In my having suggested this nomination, I hope, Sir, you will do me the justice to believe that I had not the most distant intention of anything that could possibly militate against any claim Mr. Hagerman may have to the honorary distinction of a silk gown." [32]

The house temporarily provided for the County of King's Bench at York was wholly unfit, and Samuel Ridout, the Sheriff, wanted a warrant to pay two years' rent at £40 a year (Oct. 20, 1819-Oct. 23, 1821).

The Government House, on lots 23 and 26, south side of Russell Square, built of wood, was insured in the Phoenix Insurance Company of London, England, for £3,000, currency ($12,000) for a premium of £37 10s. and 5s. for the policy, April 1, 1822.

John Beverley Robinson, in London, April 22, 1822, writes Hillier that "Mr. Gourlay has just published his Statistics in three volumes full, I am told (I shall get it to-day), of his old grievances;" and of a surety he had not been much misinformed.

Major McNabb, Sergeant-at-Arms, June 7, 1822, nominated his son, Allan Napier McNabb, as Deputy Sergeant-at-Arms. Did either foresee that the young man of 24 was to become a baronet and Prime Minister of Canada?

Anne Powell, the self-willed but talented daughter of the Chief Justice, met a watery grave off the Head of Kinsale when the *Albion* from New York was wrecked, April 22, 1822—the second of her family to sink beneath the waves, for her brother Jeremiah had perished at sea nearly fourteen years before.

The will-o'-the-wisp of Perpetual Motion was not unknown in our Province. John Thomas of "Gananock, upper candy," writes to the Governor in March, 1822: "On the fifth of march i praid ernestly to GoD to revel the perpetul motion to me if it was consistent to his will and that night I dremp that i saw two machines that went perpetully i saw a whele that went perpetully it was three feet in sercumference and twenty three peces of steel fasned in the rim of the whele all of an epull Distence a part and a pece of tode stone three inches from the rim of the whele wich a tracted the steels and thare ware copper slides that shed back and furred over the steels on the whele went round when a steel got in range with the tode stone the

[32]Campbell's letter is dated May 28, 1822.

Campbell writes July 8, 1822, that Hagerman had called on him and said he was to accompany the Judge as Counsel for the Crown.

slide stiped over the steel wich brok the atraction be twen the todestone and that steel and a tracted the next as the whele went roun and keep the whele continullly wherlling i shall not mention the other matter untill i no your mind a bout this." The Secretary endorses this lucubration, "Mr. John Thomas has discovered (or dreamt he had) the perpetual motion, March 5, 1822."[33]

"Quid est quod fuit? ipsum quod futurum est. Quid est quod factum est? ipsum quod faciendum est. Nihil sub sole novum, nec valet quisque dicere: Ecce hoc recens est; jam enim praecessit in saeculis, quae fuerunt ante nos."

The words of the Preacher came into my mind when, intending to prepare this address, I made an examination of the "Sundries, U.C.", in the Dominion Archives.

The very first paper which caught my eye was a letter from my own county, Northumberland. John Smith, of Lot No. 3 in the 8th Concession of Cramahe, writes, October 29, 1822, to Major Hillier:

"As the lumbermen are committing sad depredations in this neighbourhood by plundering indiscriminately the lands of the Crown and those of private individuals to the ruin of the lands and great detriment of the country," he asks that this practice be stopped. Major Balfour of Percy said that he had no authority to stop the depredations. Smith wishes "any communication for me to be addressed to Major Bafour . . . to prevent suspicion and avoid the revenge of these robbers . . . on some of the lots there is lumber enough now cut to pay for 40 years' lease. . . ."

Not receiving any reply—apparently the Crown Lands Department of the day was supine—Smith writes again, November 23, 1822. He said that he had written, October 29, concerning the depredations

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[33]The idea is clear enough: Thomas thought that the interposition of a copper screen would prevent the action of the loadstone on the steel—the steel approaching the stationary loadstone, being bare, would be attracted by it; but as soon as the steel was past the loadstone, the copper screen or slide slipped over the steel and it was no longer attracted by the loadstone. This is almost identical with the scheme in the Ency. Brit., vol. 21, p. 182; the fallacy is obvious.

The dreamer writes "todestone" but, of course, he means "lodestone;" he once writes "whele" as "whete"; "stiped" is 'slipped".

When I began the practice of law an inventor called on me time and again with a scheme for perpetual motion: I refused to look at it or consider it (I had received my degree of B.Sc. some years before). I told him to bring me a working model and I would give him $100. Over and over again he brought descriptions and sometimes part of a machine which "would work" or was "going to work"; but I always refused to look at anything that did not actually work. I never got one, and till the day of his death Moffat felt hardly toward me because I would not pay him for something he was sure would work but which never did.

and enclosed a copy of the letter; he had sent the former letter by private conveyance and was afraid that it had miscarried. He adds that the amount of depredation in this year is without parallel, principally by Americans (*Nihil sub sole novum*) who boasted that they would leave the land not worth a farthing for 40 years to come.[34]

I pass over the interesting attempt of the Lieutenant-Governor to act as Chancellor in an "Ordinary" or "Common Law" Court of Chancery, to repeal a patent of land granted in Lanark to Samuel Swan in error—this is too technical to be dealt with here.

My old town of Cobourg was, August 2, 1821, granted a "Fair." [35] Subscriptions were asked, November 8, 1821, by a committee headed by Joseph Hume for a monument to the Duke of Kent.

The English Methodists were withdrawing from Upper Canada (except the Garrison at Kingston). They did not wish to carry on a warfare with the American branch as there was no evidence of interference in political questions by the ministers of the Methodist-Episcopal Church and the prejudice against them was unfounded.

The Reverend John Barclay, clergyman of the Church of Scotland at Kingston, wanted an allowance, and asked Hillier in what part of the "Scotch Established Church" in Kingston the Governor's seat be placed, stating that in Quebec it was on the front of the gallery opposite the pulpit.—*Estote prudentes sicut serpentes et simplices sicut columbae.* His *confrère*, the Reverend John McLaurin, Minister of Lochiel, U.C., who went there in 1820 and was paid £60 a year "most in kind," had a congregation of 1,200 souls able to attend church from the townships of Lochiel, Kenyon, Hawkesbury and Caledonia—he also thought that the Scottish Clergy should be provided for. There were only four of the Established Church—

[34]Lot 3, Con. 8, Cramahe, is now in the Township of Brighton—there is a mill privilege on the lot; the village of Codrington is on part of it.

Henry John Boulton, the Solicitor-General, wrote Hillier from York, May 23, 1822, stating that the constable had been prevented from arresting two men stealing timber at the River Credit and he asked for a military force. Andrew Wharffe, the Deputy Collector, was instructed by Boulton to seize two vessels at the mouth of the Credit River loaded with staves for export: he met with forcible opposition.

[35]The patent was issued to "John Spencer and his successors in office as sheriff;" it was of a public fair "with all the privileges, customs, usages, court of pie powder," incident to fairs and the laws of fairs—the fair to be held "in the town of Cobourg in the township of Hamilton in the District of Newcastle." The grant is endorsed with the fiat of John Beverly Robinson, Attorney-General, and is dated August 2, 1821. This is the first notice of Cobourg which I have seen—the town had been called "Hamilton."

Port Hope, seven miles west, got a fair the same day with the same provisions, the grantee being John Hutchinson.

himself, Mr. Barclay and Messrs. MacKenzie at Williamstown and Leitch at Cornwall. There were some 18 other Presbyterian clergymen in the Province—some of the Secession Body in Scotland, some of the Synod of Ulster in Ireland, some of the Independents in England, and two or three or four from the United States—he thinks that "the Methodist and Presbyterian clergymen who reside in this Province from the United States must operate strongly in alienating the minds and affections of His Majesty's loyal subjects. "I have been told by a respectable English Methodist preacher that a preacher from the United States harangued a large audience on a Sunday lately on the probability of the Provinces falling to the States in the event of war with Great Britain, and the beneficial effects which would flow to the inhabitants of this Province from such an event. Such things call strongly for the interference of the Legislature." He did not ask for any governmental provision for *them.*

On the other hand, the Reverend S. J. Mountain of Cornwall complains, October 7, 1822, of the trustees of the District School dismissing Mr. James to appoint "a Presbyterian clergyman from Scotland on his arrival in this country", and he fears" injurious influence upon the principles of the children of the Church of England here."

I close this discursive and already too long paper by a reference to one of the most picturesque of our Canadian immigrants. Lord Dalhousie, October 4, 1822, writes to Maitland introducing "Mr. McNab, a gentleman of great respectability from the Highlands of Scotland, who proposes to make a hasty tour in the Upper Province and desires to make his bow to you."

I shall succeed in my object if I induce you and others to consult this fascinating collection of documents.

A Chapter of Canadian Economic History, 1791 to 1839

By JAMES MAVOR, PH.D., F.R.S.C.

(Read May Meeting, 1922)

The seigniorial system was in effect confirmed by the Quebec Act of 1774,[1] which provided that in all matters of controversy resort should be had to the laws and customs of Canada,[2] although there was also provision in the same Act for holding land in free and common soccage. The Quebec Act erected into one province all the territory north of the New England colonies and of the province of Pennsylvania, westwards along the Ohio River to the Mississippi and northwards to the boundary of the territory granted to the Hudson's Bay Company.[3] The Act, which was designed to placate the French-Canadian population, had the effect of an irritant upon the colonists of British extraction both in Canada and in the older British colonies. The hostility with which it met led to the Act of 1790-91,[4] by which certain parts of the Quebec Act were repealed, the two provinces of Upper and Lower Canada erected and all land grants in Upper Canada required to be made in free and common soccage, the same tenure to apply in Lower Canada should the grantee so desire.[5]

The Act of 1790-1, known as the Constitutional Act, gave Canada representative institutions and recognized the localization in two different regions of the two dominant races, placing each of them under the laws and customs to which they were respectively habituated.[6] The two provinces were separated in respect to administration, but their financial affairs were inevitably confused, because the bulk of the imports of Lower Canada were destined for consumption in the Upper province and the proportion of customs revenue which should fall to each was a constant cause of controversy and a frequent subject of readjustment. The separated provinces were reunited in 1840.[7]

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[1]14 Geo. III, c. 83.

[2]*Ib.*, cl. VIII.

[3]*Ib.*, cl. I.

[4]31 Geo. III, c. 31.

[5]*Ib.*, cl. XLIII.

[6]For the various drafts of the Constitutional Bill see *Canadian Archives, Documents Relating to the Constitutional History of Canada, 1759-1791*, ed. Shortt and Doughty. Ottawa, 1907. For account of the controversy see Sir C. P. Lucas, *A History of Canada, 1763-1812*. Oxford, 1909.

[7]3 & 4 Vict., c. 35.

The new constitution of 1791 gave Upper Canada a Lieutenant-Governor subordinate to the Governor who resided in the Lower province. The first Lieutenant-Governor of Upper Canada was Lieutenant-General Simcoe. His business, as he evidently conceived it, was to establish the province on a sound economic basis. He proposed to form a kind of industrial army consisting of a corps independent of the troops of the line. This corps was to be employed for the construction of public works. He proposed to establish a capital and to concentrate immigrants in its neighbourhood;[8] and he proposed that since the great need of the country was ready money that the British Government should send out a large sum in gold.[9] He disapproved of the reliance placed by some in the fur trade; and he thought that this trade should be left wholly to the companies in the North West.[10] He insisted upon the immediate establishment of two schools, one at Kingston and one at Niagara, and the speedy establishment of a University at the capital. The projects were formed before he left England. They are strongly infected with contemporary enthusiasm for industrial and commercial development and are coloured by the military notions of the time. Simcoe's dislike of the fur trade was quite in keeping with this enthusiasm. The interests of the fur traders lay in preservation of the primitive condition of the country, in prevention of settlement and in discouragement of agriculture and free commerce. The germ of American capitalism on the large scale had lain in the fur trade, and there is little doubt that had the colonies in revolt been able to secure the adhesion of Canada, the powerful influence of the fur traders would have been exerted to keep the country as long as possible as a forest preserve and to prevent settlement. Although there were Englishmen in the fur trade, the general view of commercial development prevalent in England at that time was not that of the fur traders. The commercial magnate undoubtedly wanted monopoly; but the merchants of middle rank, who were becoming numerous and politically influential before the end of the eighteenth century, wanted freedom of trade in every direction, and Simcoe seems to have represented their views. As usual in such cases, Simcoe underestimated the element of time. His more important projects were eventually carried out but at a much later period.

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[8]Simcoe to Dundas, June 2, 1791. State Papers of Upper Canada. Q. 278. Calendared in *Report of Canadian Archives*. Ottawa, 1891. Sect. VIII, p. 1.

[9]Scott, Duncan, Campbell. *J. G. Simcoe* in Makers of Canada Series, Toronto, 1905, p. 111.

[10]Simcoe to Dundas, April 28, 1792, p. 11.

In spite of the difficulties attendant upon the organization of an infant colony, the first year of the new province gave it a not unfavourable start. The harvest of 1791 was abundant and in the following year immigrants began to pour in. Indeed the home government at this time feared that immigration into Canada was being overdone.[11] Simcoe remarks upon "the poor and dispirited state of too many of the population." [12] Yet wages were high,[13] although capital, public as well as private, was scarce. Coins, though very numerous in respect to character,[14] were not plentiful and exchange in kind was common. Many services were paid for in kind as well as partly in kind and partly in money.

It appeared to Simcoe and to others that the two pressing needs of the province were people and capital. The country could not be maintained as a political entity without people and the resources of the country could not be exploited without men and money. The immigration which was taking place was chiefly from the United States; the attraction of gratuitous lands sufficed to draw many who were indifferent upon the question of allegiance; of overseas immigration there was little; the voyage was long and relatively expensive. The increase in the population of England between 1790 and 1800, although greater than in the preceding decade, was scarcely such as to justify belief in redundancy of population, yet deficient harvests—in each year between 1792 and 1795, in 1799, 1800 and 1804, impoverished the people and contributed to enormous increase in the poor rates.[15] There were numerous schemes for the diminution of these through the organization of the labour of the poor, but practically all of the schemes, including Pitt's Plan of 1796, reverted to the poor law doctrines of the reign of Elizabeth; they did not contain any projects of emigration or of colonization. Such projects did not come till a later period.

The earliest attempt at colonization was not made on philanthropic grounds but probably through a mere caprice by a former

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[11]Dundas to Simcoe, July 12, 1792, p. 13.

[12]Simcoe to Dundas, Sept. 20, 1793, p. 24.

[13]*Ib.*

[14]Under 36 Geo. III, c. 1 (1796) (Provincial Parliament of Upper Canada), the British guinea, the Portuguese *johannes* and moidore and the American eagle were legal tender in gold, and the British crown and shilling, the Spanish milled dollar and pistareen, the French crown, and the French pieces of four livres, ten sols, of thirty-six sols and of twenty-four sols Tournois and the American dollar were legal tender in silver.

[15]See *e.g.*, Malthus, *Essay on the Principle of Population*, 8th ed., London, 1878, p. 212.

private secretary of Simcoe, Colonel Thomas Talbot. As a field officer he was entitled, under the provision of the law at the time, to a grant of 5,000 acres. He began his settlements personally in 1803 at Port Talbot on Lake Erie near the present city of St. Thomas.[16] Altogether he obtained, on condition of securing colonists, direct grants of land amounting to 65,000 acres.[17] But this represented only a small part of the area dealt with by Talbot. In consequence of grants or instructions by Orders-in-Council or personal orders from the Lieutenant-Governor, the total area amounted to 540,443 acres.[18] Actual settlement began in 1809. The first settlers, who were from Pennsylvania, were of Irish extraction; then came a number of Scots Highlanders, Quakers from Pennsylvania and New Jersey, and settlers of miscellaneous origins from New York State, from Nova Scotia and from the south of England. A group of settlers came from Ireland. These various groups were settled in the region controlled by Talbot prior to the outbreak of the war in 1812. When that event occurred immigration from the United States ceased and the frontier settlements were overrun not merely by troops during military operations, but also by armed bands of marauders who carried off or destroyed the property of the settlers.[19] After the close of the war in 1814 five years elapsed before immigration on any scale into the Talbot settlement was resumed. In 1819 a group of Argyllshire Highlanders settled at Aldborough and further settlements ensued later. Talbot appears to have been a severe administrator of his large property. He compelled the settlers to live up to their contracts with him at a time when the government was unable to enforce discharge of their obligations to the State.

Up till 1819 the settlers in Upper Canada were distributed along the shores of Lakes Ontario and Erie in a discontinuous line of settlements. The interruptions were caused partly by choice of locality on the part of individual settlers or of groups, partly by Indian Reserves like the Reserve of the Mississagas which landwards cut off York (Toronto) from the settlements westwards along the shore of Lake Ontario, and partly by unoccupied tracts of land, portions of

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[16]On the Talbot settlement see *Canadian Archives* Reports, Ottawa, 1891, pp. XLII and XLIII, and 1903, pp. XXII and XXIII; Coyne, James N., *The Talbot Papers, Edited with Prefaces, Introduction and some Annotations.* From *Transactions Royal Society of Canada*, Ottawa, 1908; and Ermatringer, C. O., *The Talbot Regime or the First Half Century of the Talbot Settlement*, St. Thomas (Ont.), 1904.

[17]Coyne, *op. cit.*, p. 32.

[18]*Ib.*, p. 37.

[19]*Ib.*, p. 40.

undeveloped land grants. In 1819 some settlers went on the uplands of the interior towards Lake Huron. One of the first of these groups was a band of fugitives from Lord Selkirk's Red River Settlement, who settled in what is now the county of Simcoe;[20] and in 1820 a group of Argyllshire Highlanders settled in Zorra (Oxford County).[21] There was within the immediately succeeding years some migration into the upland region from Lower Canada and some immigration direct or via the United States of Scots, Irish and Germans. These settlers clustered together in groups and sometimes resented the intrusion among them of any but settlers of their own race and their own religion.

From these details it will be gathered that the colonization of Upper Canada between the cession to Great Britain in 1763 and the year 1830 was unorganized and sporadic. The experiment of giving grants with the expectation of settlement had been shown to be a failure; and the experiment of giving grants with settlement conditions attached, a plan which was instituted in 1818, had not yet been in practice for a sufficiently long period to demonstrate its utility or otherwise. In effect, three-quarters of a century had elapsed and the country was still very scantily inhabited.

The slowness of this development is ascribed by Lord Durham to the policy of the Government in respect to land grants. He contrasts with much vivacity the "activity and bustle" of the United States, the good roads and the numerous settlements, with the waste and desolation of the British side of the line.[22] He vindicates the soil and to some extent vindicates also the people; and he throws the chief burden of blame upon the profuse, indiscriminate and variable methods of granting public lands. The United States, on the other hand, he says, had adopted a system which "combined all the chief requisites of the greatest efficiency." This system was uniform and had never been materially altered; it involved the sale of land at a price which rendered the acquisition of new land easy, but at the same time "restricted appropriation to the actual wants of the settler." [23] Importance must be attached to contemporary judgments by high authority, yet, on the one hand, it may be doubted whether the land system of the United States was quite so uniform or successful

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[20]Hunter, A. F., *A History of Simcoe County*, Barrie, Ont., 1909, vol. i, pp. 62, *et seq.*

[21]For a naïve account of the Zorra Highlanders see Mackay, Rev. W. A., B.A. D.D., *Pioneer Life in Zorra*, Toronto, 1899.

[22]Durham, Report, fo. edition, 1839, p. 74.

[23]*Ib.*

as Lord Durham represents it and, on the other, it may be found that there were several causes for the relative retardation of Canadian prosperity, besides the question of land grants.

The system of land tenure in vogue in the United States in Lord Durham's time was not older than 1830. The method of disposing of public lands had previously been altered with frequency. After the colonial period, and during the period of Confederation, lands were only sold in huge blocks. In 1796, U.S. public lands were ordered to be sold at auction in lots of not less than nine square miles at a minimum price of not less than $2 per acre, long periods of credit being given. In 1814 labourers appealed to Congress on the ground that they could not obtain land excepting at exorbitant prices while the sales of great blocks to speculators continued. Only in 1830 was a measure adopted which provisionally endowed squatters with certain rights. This measure became permanent in 1842. It was not really until the passing of the Homestead Law of 1862 that a popular measure of land reform was adopted.[24] Lord Durham's encomiums upon land administration in the United States are thus scarcely deserved. The "activity and bustle" which he noticed resulted from the concentration of people in towns, due on the one hand to the development of capitalistic industry, and on the other to the impossibility of obtaining land which the labourer without capital experienced; in other words, to the forced proletarianization of the labourers. Some of the Italian economists, *e.g.*, Ricca Salerno, Loria and Rabbeno, as well as the German agronomical writer, Max Sering, have sharply criticized the land policy of the United States at this period. They regard the land policy as being in perfect accordance with the commercial policy of the United States. Large speculative enterprises were, they say, deliberately encouraged by Congress and the labourers who petitioned in vain in 1814 for allotments of 160 acres of land at 12½ cents per acre were compelled to resort to the towns for employment. Industry was thus forced on two sides—on the side of protection and on the side of refusal of land grants in order to prevent the competition of agriculture in the struggle for working hands which free or cheap land would have implied.[25] The consequence of this "overaction in all the depart-

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[24]For the land policy of the United States, see importantly Sering, Max., *Die landwirtschaftliche Konkurrenz Nordamerikas in Gegenwart und Zukunft*, Leipzig, 1887, pp. 111 *et seq.* For a summary statement see Rabbeno, Ugo, *The American Commercial Policy*, London, 1895, pp. 176-178.

[25]The association between the division of property in land into large shares and the growth of arts and manufactures is noticed by Malthus.

ments of business" as President Van Buren described the situation in his message to Congress in September, 1837, was the panic of that year.

The Struggle of the Commercial Interests

The period between 1820 and 1840 was most critical in an economic as well as in a political sense, for the Upper and Lower Provinces. The political difficulties were due partly to causes racial, social, and even personal, and partly to causes definitively economical. The latter only need concern us in this place. The French population were habituated to a life predominantly self-contained. They did not produce for the market and their consumption of commodities other than those produced by them was very slender. Capitalist organization was, therefore, unnecessary for them,[26] and their leaders even protested against it. The earliest British emigrants—the United Empire Loyalists—had been accustomed in New England and Virginia to a rapidly developing commerce in which capital was largely employed. They were deprived of what means they had during the seven years of Revolutionary warfare, and although they were compensated by grants of land, they were helpless without the supplies of capital to which they had been accustomed. Their standard of living was reduced, and they presented slender effective demand for general commodities. They had plenty of land, but they could neither borrow upon that nor sell it, and they suffered for years from the distresses of a population whose only fund is in land. In the early part of the nineteenth century, capital in Europe was much in demand both for war and for industry. It was, therefore, relatively scarce and dear. Even if it had been otherwise, the credit, both public and private, of a remote and little known colony was insufficient to attract the supplies of capital which would have permitted the extensive borrowing necessary for speedy development. In view of the relatively slow increase of population, embarkation by public or private enterprise in works of public utility formed the only means at once of promoting economical development and of organizing supplies of capital. The successful promotion of such enterprises, however, depended upon the coincidence of credit and a favourable external money market; but neither of these conditions existed.

The public revenues of the provinces at this time may be divided into three fractions. The first was the revenue derived from Customs

[26]It is alleged that the habitants hoarded coin both before and after the conquest. *Cf.* Shortt, Adam, *Early History of Canadian Banking Currency and Exchange*, Toronto, 1897, p. 3.

Duties; the second the revenue derived from the casual and territorial revenues of the Crown, and the third the revenue from license-fees and the like. The customs duties were determined by the British Parliament and the revenue from them was divisible in proportions arranged between the two provincial governments.[27] The control of the casual and territorial revenues was retained by the Imperial authorities for expenditure in connection with the administration of the provinces. The only revenues whose collection and control resided in the hands of the provincial legislatures were those derived from licenses and fees. Division of the customs revenues was the occasion of continuous disputes and adjustment between the provinces, and the control of the casual and territorial revenues was a source of continual friction between the Colonial Office and the Provincial Assemblies. The patronage in the hands of the Crown, which involved certain economical aspects, was also provocative of much friction. The difference in the economical structure of the two provinces resulted in the chief demand for imported goods being from the Upper Province, although the preponderance of population resided in the Lower Province and the greater part of the revenue was collected there. The effect of the division of the customs revenue between the provinces on any terms upon which they could mutually agree was that the Lower Province had more than it could utilize, and the Upper Province, almost destitute of means of communication as it was, less than it could have utilized.

In 1822 a Bill was introduced in the House of Commons, having for its object the union of the provinces; but both provinces objected to its provisions, and it was withdrawn.[28] The causes of friction mentioned, together with other influences some of which will presently occupy our attention, brought about the situation which led to the armed rebellion in both provinces in 1837, and eventually to the union of the two provinces in 1840.[29]

In 1792, immediately after the passing of the Constitutional Act, an attempt was made to establish a bank; but the character of the project is not known, the scheme never having matured.[30] Nothing

[27]Under 37 Geo. III, c. 12 (1797) (Provincial Statute of Upper Canada) and subsequent statutes.

[28]Cf. evidence of the Right Hon. J. W. Horton, M.P., in *Minutes of Evid. before Select Committee on the Civil Government of Canada* (London), 1828, 569, pp. 299 *et seq.* See also on the *Financial Difficulties of Lower Canada, Quebec Gazette*, December, 1824. In this article there is a long discussion of the friction between the two provinces in respect to the division of the Customs Revenues.

[29]Under 34 Vict., c. 35, 1840 (British Statute).

[30]*Cf.* Shortt, Adam, *The Early History of Canadian Banking Origin of the Canadian Banking System*, Toronto, 1896, p. 8.

further appears to have been done until 1808, when a Bill was introduced in the Lower Canada legislature providing for the incorporation of a bank in that province.[31] The capital stock of the bank was to be £250,000 in addition to any subscription made by the provincial government, which subscription was not to exceed £50,000. No shareholder not a resident of the province could be elected a director. In the event of the subscription by the provincial government of not less than £25,000, two directors might be appointed by it—one for Montreal and one for Quebec. The Bill failed to pass and the question of the foundation of a chartered bank remained in abeyance for several years. Meanwhile, the needs of the commercial community brought about the formation of four private banks whose business was carried on without any charter. The first of these was the Bank of Montreal, which began as an unchartered bank in 1817. The others were the Quebec Bank, the Bank of Canada at Montreal, and the Bank of Upper Canada at Kingston.[32] An anonymous pamphleteer of 1820,[33] in a rather verbose paper attacked the private banking system, alleging that the competition of numerous banks resulted in undue expansion of credit with consequent inflation of trade and temporary advance of prices. That there was ground for these criticisms there can be little doubt. After the banks were chartered their loans and discounts considerably exceeded the capital plus the deposits.[34]

The first Upper Canada Bank Act, chartering a bank of that name, was passed in 1817, but was reserved. Assent was eventually given in 1821;[35] but the Act had had to be introduced and passed again as the period during which assent might be given had expired. The second Bill was, however, not quite the same as the first. The Act as eventually passed contained a new provision which was obviously taken from the Quebec Bill of 1808, permitting the provincial government to hold stock in the bank. The passing of the Act was accompanied by a dispute between merchants of Kingston, who were themselves promoters of a Bill for the establishment of a bank there,

[31]*A Bill introduced in the House of Assembly of the Province of Lower Canada to incorporate a Bank in Lower Canada*, Quebec, 1808.

[32]The Articles of Association of these private banks are in general similar to the provisions of the Bill, 1808, cited above. Prof. Shortt says that they are really copies from the first charter of the Bank of the United States (Shortt, *op. cit.*, p. 18).

[33]*An Inquiry into the origin and present system of Colonial Banks and their dangerous effects, with a proposition for a National Bank*, Quebec, 1820.

[34]See *e.g.*, *Journals of the House of Assembly of Upper Canada*, Sess. 1837; Toronto, 1837. Bank return in the *Report of the Select Committee (on the) Monetary System of the Province.*

[35]59 Geo. III, c. 24 (U.C. Statute).

and the group in Toronto known as adherents of the "Family Compact." The latter party was able to carry its Bill by a small majority.[36] Thus, from the beginning, the Bank of Upper Canada was a political institution and as time went on it appeared to be employed increasingly for political purposes. In 1829 the Finance Committee of the House of Assembly denounced the Bank as a party instrument, recommended that the shares held in name of the province should be sold by auction and that the funds so derived should be expended in improving the roads and bridges. "It cannot be concealed," the Report says, "that (with whatever reason) the opinion is widely diffused that it (the Bank of Upper Canada) is a political engine of dangerous power, unsuitable for so young a province in which, unhappily, political and party strife have, during the late administration, made up half the business of life."[37] The most acute and formidable critic of the Bank of Upper Canada and of its relations to the members of the "Family Compact" was William Lyon Mackenzie, who became in 1829 a member of the Provincial House of Assembly for the county of York. Mackenzie had undeniably a talent for public financial legislation. His temperament might have unfitted him for administration; but as financial critic, the various reports of which he was the author reveal him in a highly favourable light, although the asperity with which he catechized witnesses before the various committees of which he was a member militated against his obtaining any information or even admissions from them.

In 1830 Mackenzie moved for a Select Committee on currency and became chairman of it. The report, obviously his handiwork, was presented on the 11th of February, 1831.[38] The chief points in this report are of consequence, because they appear three years afterwards in substantially the same form as the marrow of a Treasury Memorandum.[39] In his report Mackenzie recommended that the following precautions against unsound banking should be embodied in a general Act: (1) That failure to redeem the paper of a bank should be followed automatically by dissolution of its charter; (2) that

[36]For a brief account of the dispute see Shortt, A., *The Early History of Canadian Banking. The First Banks in Upper Canada*, Toronto, 1897. *Passim.*

[37]*Journals of the House of Assembly*, Toronto, 1829. March 8th, 1829, Report of Finance Committee XII, Bank of Upper Canada (not paged). *Report of the Select Committee appointed to examine and report on the expediency of establishing a Provincial Bank within this province,*" 13th Feb., 1835.

[38]Report of Select Committee on Currency, 11th Feb., 1831 (Signed W. L. Mackenzie), in *Sundry Documents,* Journals of the House of Assembly of U.C., Sess. 1831, York, 1831, p. 201.

[39]See *infra.*

dividends should be paid only out of actual profits; (3) that the stock of the bank should not be pledged for discounts; (4) that non-resident stock-holders alone might vote by proxy; (5) that either branch of the legislature might appoint persons to ascertain the financial position of the bank; (6) that the legislature might, if it saw fit, prohibit the bank from issuing notes of a smaller denomination than five dollars; (7) that the registers of the names of stock-holders should be open to the stock-holders prior to the meetings at which directors were to be elected; and (8) that full statements on a form to be prescribed should be required of the banks periodically. These recommendations and the draft Bill which embodied them were ignored and, on this and other grounds, Mackenzie developed a series of attacks upon the executive and upon the majority in the Provincial Assembly in his newspaper, the *Colonial Advocate*. In an article published on the 1st of December, 1831, he was especially bitter on the banking question: "Are we not now," he wrote, "even during the present week, about to give to the municipal officers of the Government, as a banking monopoly, a power over the people which, added to their already overgrown influence, must render their sway nearly as arbitrary and despotic as the iron rule of the Czar of Muscovy?" [40]

The executive and the majority of the House of Assembly exercised their power, expelled Mackenzie on the 12th of December, and ordered a new writ for the election of a member in his place.[41] Mackenzie was returned on the 2nd of January, 1832, and on 5th January repeated his denunciations in the *Colonial Advocate*, launching into a general philippic. On the banking question he wrote: "They (the majority) get rid of bills for the general regulation of banking, revenue enquiries, enquiries into salaries. . . . They (the majority) are chiefly placemen . . . who receive from the government six, if not ten, times the amount they obtained from the people as legislators. . . ." [42] On the following day, on the motion of the Solicitor-General, Mackenzie was again expelled, and again a writ was issued. The new election began on the 30th of January, and Mackenzie was again returned. While Mackenzie was under expulsion the House of Assembly passed the Bank Acts to which he had objected. Then

[40] *Colonial Advocate*, 1st December, 1831.

[41] Lindsey, Charles, *Life and Times of W. Lyon Mackenzie*, Toronto, C.W., 1862, vol. i, p. 222.

[42] *Colonial Advocate*, 5th January, 1832.

Mackenzie hurried to England, laid his complaint before the Colonial Office, and secured the disallowance of the measures.[43]

In 1834 a Select Committee was appointed to report on the expediency of establishing a provincial bank. This committee reported in 1835,[44] advising that the province was much under-supplied with banking capital as compared with the state of New York. From the evidence brought before the committee it was clear that Canadian external trade was being carried on under great disadvantages. The rate of exchange was enormous. The Bank of Upper Canada was importing both gold and silver; but these were steadily drawn away. This phenomenon was attributed to the under-valuation of the coins. In other words, the paper of the banks was depreciated, and this fact was not recognized. Mr. Ridout, of the Bank of Upper Canada, suggested that the sovereign should be reckoned at £1.4.3, and the crown at 6s.[45]

Mackenzie appears at this time to have had in his mind the establishment of a national bank either on the plan of the National Bank of the United States, which was actually in existence, or on the plan of Ricardo published in 1824, after the death of the author.[46] Mackenzie cannot be supposed to have been fully aware of what was going on in the financial world; but his insistence upon sound banking was as strenuous as if he had been fully informed. In 1836, owing to the first railway mania in Great Britain and other causes, there was great financial stringency, and in 1837 there was a commercial crisis in the United States arising from undue expansion of credit. These occurrences cut off the supply of capital which, small though their operations were, the Canadian banks urgently required. No banking system is proof against widespread panic; but the extent to which the Canadian banks had extended their credit rendered them peculiarly vulnerable. Oblivious of the external and internal financial situation, the Upper Canada Government proposed, in 1836-37, a series of measures involving an expenditure very large relatively to the resources of the province at that time.

Sir Francis Bond Head, who was then Lieutenant-Governor, felt himself obliged to summon the Provincial Parliament for an extra-ordinary session, and in his Speech from the Throne on 20th June,

[43]*Cf.* Lindsey, Charles, *The Life and Times of Wm. Lyon Mackenzie . . .*, Toronto, C.W., 1862, vol. i, p. 243.

[44]Report of Select Committee on the expediency of establishing a Provincial Bank within this Province (Upper Canada), 13th February, 1835.

[45]Evidence of Ridout in Report of Committee on Finance, 8th March, 1829.

[46]*Plan for the establishment of a National Bank*, London, 1824 (pp. 499-512 in McCulloch's Edition of Ricardo's Works, London, 1881).

1837, he counselled the suspension of specie payments by the banks.[47] This measure was, no doubt, wise under the circumstances, since it would have been difficult for the weak Canadian banks to have protected themselves against the complete withdrawal of their small amount of specie to the United States during the suspension there of specie payments; but on the face of it, and external influences apart, it strongly confirmed the attitude towards the banking question which Mackenzie had maintained for the previous eight years.

Mackenzie had been elected and expelled five times in succession, and his constituency was for a time practically disfranchised. It is difficult to dissociate these repeated expulsions from the irritation produced in the minds of his opponents by his persistent and vigorous attacks upon their financial methods. The armed disturbances in the Lower Province, which had partly a racial and partly an economical foundation, seem to have suggested to Mackenzie similar action in Upper Canada, and he engaged impulsively in what is known as the Rebellion of 1837. Not for three or four years did the country, now once again united into one Province, assume a normal economical or political condition.

To interpret the Rebellion of 1837 in Upper Canada fully, would require a more extended exposition than would be appropriate to an economic history in the strict sense, but some brief suggestions may be offered. The activity and bustle which Lord Durham notices in the United States, and Mackenzie also notices in his "*Sketches*," had evidently impressed itself,[48] especially upon new comers. Lord Durham must have derived his knowledge of the United States almost wholly at second hand. Mackenzie arrived in Canada from Scotland in 1820, at the age of twenty-five; he visited the United States for the first time in 1829. The furore for industry, which has already been noticed, was in full vigour. The towns were crowded with people and there was bustle and movement everywhere.

Prosperity was abundant and obvious. Protectionists were ascribing it to the tariff of 1828; others looked upon it as occurring in spite of the tariff. It seems to have been due principally to the influx of population from Europe, to the difficulty which the newcomers experienced in obtaining land, to the consequent abundance of hirable labour and to the energy with which the capitalists, who

[47]An Act (7 & 8 Will. IV, c. 2) was passed on 11th July, 1837, permitting chartered banks to refuse to exchange specie for their notes without forfeiting their charter.

[48]See *Sketches of Canada and the United States*, by W. Lyon Mackenzie, London, 1833.

had been gradually accumulating means, threw themselves into manufacturing enterprises and speculations of many kinds.

The contrast between the United States and Canada was clear. The surviving United Empire Loyalists and their friends, who formed the superior layers of society in Upper Canada, were not much interested in business. Many of them were cultivated people, but they lacked enterprise and energy. Above all, they had no money. Even the best of them were heavily indebted to the government and to other creditors. Mackenzie unconsciously represented the new commercial spirit,[49] however ineffective he might have shown himself in expressing it in organizing capacity. He represented it in the same way as Simcoe and Lord Durham had represented it.

The merchants of Kingston, who had promoted the bank in opposition to the group at York, represented it also as did very many of Mackenzie's sympathizers. Out of about 900 persons accused of complicity in the rebellion who were arrested or who were able to abscond in 1837, more than 140 belonged to the professional, mercantile and industrial classes, and the remainder were farmers in the immediate neighbourhood of the urban centres and labourers living in the towns or indirectly dependent upon them,[50] most of the latter being probably unemployed. The attacks upon the executive were nearly all in respect to finance—to the provincial

[49]The following extract from the *Colonial Advocate* illustrates the text and is given here because there is only one known set of the newspaper, which set is in the possession of the family of the late Mr. G. G. S. Lindsey, of Toronto. Mr. Lindsey was good enough to furnish me with the extract:

"Lands and tenements are a drug in the market; property does not average one-fifth of what its value is on the opposite side of the lake; sheriff's sales increase in number and value; ∴ the province, beautiful, fertile, well-watered and extensive as it is, fails to attract or retain population; men of capital and enterprise, if possessed of manly feelings, remove from a petty tyranny they cannot but dislike, and mechanics from Europe find no rest for the sole of their feet until they enter the territories of the Republic. . . . Domestic manufactures of every kind, unless perhaps in a few extraordinary cases, where favourites of the executive have been deeply concerned, are directly and indirectly discouraged; and bills passed by the local Assemblies for promoting Canada manufactures are thrown under the table by the peers, as interfering with the main object of a colony, to wit, the promotion of the trade, and enlargement of the patronage of the Mother Country. Attempts to pass acts for the improvement of the roads and bridges have been equally unsuccessful, although our roads are in general in a wretched condition, and the situation of many of the back settlers so miserable as to render them objects of pity and commiseration in the eyes of any government other than a colonial one. The only bank in the colony is virtually under the control of the executive. . . ."—*Colonial Advocate*, 2nd July, 1829.

[50]See the lists of persons involved in the Rebellion, printed as an appendix in Lindsey's *Life of Wm. Lyon Mackenzie*, Toronto, 1862, vol. ii, pp. 373-400.

revenues or to banking and to the absorption of credit for their own purposes. The demand for responsible government appears as a means to an end—the end being the industrialization of the province. That this was the conscious end, is not suggested; that it was the consequence of the rebellion, and of the subsequent responsible government, there can be no doubt.

The Colonial Policy of the Dominion

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(Read May Meeting, 1922)

The development of the provinces of the Dominion from definitely colonial status has been so prolonged and gradual a process that a similar development within Canada itself has been almost completely overshadowed. As early as Confederation itself an imperial *rôle* was contemplated in general terms towards those vast areas in the West which remained after the rapid disintegration of Hudson's Bay rule. Over these territories the first parliament of the Dominion, in December, 1867, prayed to be allowed to assume the duties and obligations of government, but it would be safe to say that few were aware of the difficulties of such a sponsorship and that none realized its implications.

The original Confederation was singularly ill-equipped for such a *rôle*. Section 146 of the *B.N.A. Act* of 1867 provided for the future union of Rupert's Land and the North-Western Territories to Canada "subject to the provisions of this Act." According to "the provisions of this Act" the control of the Crown lands was vested exclusively in the provinces. The federal government, in fact, was not legally a landed entity; while the transfer of Rupert's Land and the North-Western Territories in 1870 involved the administration of one of the largest areas of ungranted Crown lands within the British Empire.

The Dominion undertook to create the new province of Manitoba at a time when the *Manitoba Act*, on the advice of the best legal opinion then and since, was in many important respects *ultra vires* of the federal government. The Dominion proceeded nevertheless to legislate the new province into existence under conditions which have made of it an exception ever since to recognized British constitutional principles. In the case both of the new province and the territories it required an Imperial Act of indemnity "for all purposes whatsoever"—the *B.N.A. Act* of 1871—to confirm and regularize the ravages of political expediency.

Despite this very unpromising beginning, the stages through which these territories passed from primitive colonial status under Governor and Council in 1870 to responsible government in 1897 and provincial status in 1905, afford a very remarkable parallel to the various colonial stages of the original provinces of the Dominion.

In that comparison it will be found that the Canadian territories have enjoyed many advantages; not always, it is to be feared, attributable to the "colonial policy" of the Dominion.

In both cases there was a preliminary conciliar stage: in the one case from the *Proclamation* of October, 1763, to the *Quebec Act* of 1774, in the other from the transfer of 1870 to the *North-West Territories Act* of 1875. In both cases there was a stable and statutory period under Governor and Council: in the one case from the *Quebec Act* to the *Constitutional Act* of 1791, in the other from the *Territories Act* to its consummation in an Assembly in 1888. In both cases the contest for responsible government followed inevitably with inexorable though in some respects very dissimilar results: in the one case the *Act of Union* and the administration of Lord Elgin, in the other the contest for fiscal control and the Act of 1897. In both cases a period of strenuous politics supervenes before provincial organization in the Dominion. Here, at least, there is more of contrast than of comparison, and it must be admitted that the element of contrast still survives the achievement of provincial status.

I. From Confederation to Empire

The exercise of imperial functions by the federal government over areas in subordinate territorial status involved a far-reaching change, it would seem, in the nature and amplitude of the original Canadian Confederation.

Had the contention of the original province of Canada prevailed before Confederation, the annexation of Rupert's Land and the North-Western Territories would perhaps have raised no constitutional difficulties in the Dominion in 1867. Had the districts on the Saskatchewan and Red rivers been united to "Canada" (as the Committee of the British House of Commons recommended in 1857) as new territory was added to British Columbia in 1863, or to Ontario and Quebec in 1912, representation in the "Canadian" legislature would have followed as a matter of course. The new territory would have been upon an equal footing with the old, for the best of reasons that it would have been indistinguishable from it.

The Confederation of 1867 raised a new set of legal problems within the British Empire, but it is curious that a prospective imperial *rôle* for the Dominion with regard to subordinate territory was not immediately recognized as one of them.

The Dominion of Canada in 1867 was a Confederation of equal provinces, each, within the limits of the Act, intended to "retain its independence and autonomy, and to be directly under the Crown as its head. Within those limits . . . its local legislature . . . was to be supreme."[1] The Lieutenant-Governor thus exercises within the limits of powers reserved to the province, the amplest prerogatives of the Crown. Was the Lieutenant-Governor of the territories to exercise prerogative, or merely statutory and delegated, powers?

A similar problem arose with regard to the Crown lands. The original Dominion as such was literally landless. Even where certain lands were required for federal purposes—for Indian reserves in Ontario, railway lands in British Columbia, etc.—these were transferred by the several provinces "in trust," and a long series of cases has established the priority of provincial rights wherever public lands have been brought into question.

It would seem indeed from the *B.N.A. Act* of 1867 itself that no other arrangement was contemplated. By section 146 of that great measure the prospective union not only of British Columbia, Prince Edward Island and Newfoundland, but of Rupert's Land and the North-Western Territory, was made specifically "subject to the provisions of this Act." It is to be observed that Sir John A. Macdonald himself, in drafting the measure that has been held to have changed the whole nature and purpose, in this respect, of the original Confederation, stated that

> "Even if the terms of the Address (specified in the *B.N.A. Act*, 1867, section 146) had included a new constitution for the North-West it must, under the above cited section, have been subject to the provisions of the Imperial Act of Union."[2]

While subordinate status is not even implied in the *B.N.A. Act* of 1867,[3] however, it may not be without significance that in the *Rupert's Land Act* of the following year the phrase "according to the provisions of this Act" is omitted from that section (31-32 Vic., c. 105, s. 5) which confirms the provisions of the *B.N.A. Act* of 1867 for the union of Rupert's Land with Canada. If this omission indicates deliberate preparation for subordinate territorial status, the *Rupert's Land Act* must be regarded not only as the first amendment but in one sense the most important of all amendments to the *B.N.A. Act* of 1867. It not only provided for extinguishing—"absolutely,"

[1]Lord Haldane in the *Manitoba Initiative and Referendum Case* (6 Geo. V, c. 59). *Law Journal Reports*, November, 1919, p. 145.

[2]December 29, 1870, *Can. Sess. Papers*, 1871, vol. 5, Paper No. 20.

[3]Except in the fact that the terms of admission are not, as in the case of P.E.I., B.C., or Newfoundland, to be subject to "addresses . . . from the Houses of the respective Legislatures."

as the Act states—the proprietary system of the Hudson's Bay Company, but it must be held to have foreshadowed, even if it did not in itself effect, the transformation of the Dominion from a Confederation of equals to a veritable empire entrusted with the administration of subordinate territory under the Crown "as a part of the British colonial system."

That transformation indeed was assumed—too hastily it would seem—during the unfortunate troubles which attended the transfer in 1869-70. The federal *Act for the Temporary Government of Rupert's Land and the North-Western Territory when united with Canada* (32-33 Vic., c. 3) and the *Manitoba Act* of the following year were both passed upon that assumption; and it was deemed necessary, as already pointed out, to pass the Imperial *B.N.A. Act* of 1871 drafted at Ottawa for the specific purpose of validating (as the Act states) "for all purposes whatsoever," the irregularities committed under both measures by the Government of the Dominion.

With the *B.N.A. Act* of 1871, at any rate, it becomes possible to speak of "colonial policy" for the Dominion. As a matter of fact, the first exercise of that policy had already been thwarted by an inglorious insurrection at the Red River Settlement.

II. The Conciliar Period, 1870-1888

British government by Governor and Council began in Quebec after 1763 under very favourable auspices by comparison with those under which Canadian government was introduced into Rupert's Land and the North-West more than a century later. The *Act for the Temporary Government of Rupert's Land and the North-Western Territory when united with Canada* was passed in 1869 in anticipation of the transfer. It provided for administration by Lieutenant-Governor and Council "not exceeding fifteen nor less than seven persons." The Lieutenant-Governor elect was the Hon. William McDougall; and the whole French Roman Catholic community at Red River felt justified in regarding the prospect of such a government with undisguised uneasiness.

The Riel Insurrection which followed was technically an insurrection against the Hudson's Bay Company, since the transfer had not yet taken place. In fact it was directed against the prospect of conciliar government by the Dominion of Canada. French clerical interests had "always feared the entrance of the North-West into Confederation because . . . the French Catholic element would be sacrificed." [4] They now sought—and the French Métis by open

[4] *Vie de Mgr. Taché*, Dom. Benoit, vol. ii, p. 7.

insurrection secured—a measure of protection for their cherished privileges of language and religious education. In that sense the Riel Insurrection of 1869-70 was perhaps the promptest and the most successful movement ever directed against a form of government which has seldom been found other than transitional and unsatisfactory even under the best of circumstances.

The immediate attainment of provincial status for Manitoba in 1870 lies beyond the scope of this paper, but there can be no doubt that very early in the movement, provincial as distinct from territorial status came to be the avowed purpose of the Riel Insurrection. It was proposed by Riel and his party in the Convention of February, 1870, and though defeated on the open vote it was stipulated in the first section of the third "list of rights" published in French at the Settlement in March, 1870.[5] It was the basis of the secret "list of rights" which Father Ritchot used at Ottawa in the discussion of the *Manitoba Bill*. It seems to have been the basis of the "terms accorded to himself and his Church" with which Bishop Taché, on his return to Ottawa from Rome in April, 1870, "expressed himself quite satisfied."[6] A statute, particularly if confirmed by an Imperial Act, was naturally regarded as the most enduring of all safeguards for the French language, for separate schools "according to the system of the Province of Quebec" and for the interests of a primitive community which was certain at no distant date to find itself on the defensive.

Not only was provincial status the immediate purpose of the Riel Insurrection but this was beyond question its immediate result. It would be absurd to regard the Riel Insurrection as a "fight for responsible government" since there was much less concern for government by themselves than for "some breakwater" against domination by Canada. The poverty-stricken administration of Manitoba, with fiscal resources altogether inadequate to provincial responsibilities, was largely the result of the *Manitoba Act* at that time; but few communities have been bundled so unceremoniously into responsible government.

The inauguration of Canadian government in the remaining territory after the transfer, began more auspiciously. By the *Manitoba Act* (section 35) it was provided that the Lieutenant-Governor of the Province should be *ex officio* Lieutenant-Governor of the North-West

[5]"1. That the Territories, heretofore known as Rupert's Land and North-West, shall not enter into the Confederation of the Dominion of Canada, except as a Province . . . with all the rights and privileges common to the different Provinces of the Dominion."—*Recent Disturbances in the Red River Settlement*, 1870, p. 130.

[6]Telegram from the Governor-General to the Colonial Office, April 11, 1870.

Territories "by Commission under the Great Seal of Canada," and the original *Act for the Temporary Government* had provided, as already noticed, for a "Council of not exceeding fifteen nor less than seven persons." Some grotesque perversity of fate, however, still seemed to pursue the affairs of Canada in the West, for Lieutenant-Governor Archibald waited in vain for his "books and papers, despatched from Ottawa on the 6th August." As late as November, 1870, they "had never reached this place, and in all Manitoba not a single copy of the Acts of 1869 was to be found." The Lieutenant-Governor appointed a Council of three and issued his first ordinance on October 22, 1870, only to find that he had "been all wrong and . . . exercising functions belonging to the Governor-General." "One lesson I shall learn," he observed, "never again . . . to assume to act under a Statute on a mere vague recollection of its terms."

The prosaic records of government and legislation in the *Minutes of the North-West Council* contain much, nevertheless, of constitutional interest. The oath of secrecy was restricted to the "Executive Functions of the said Council to the exclusion of those of a Legislative character." [7] In its legislative capacity the Council took for granted the prerogative powers of the Crown in the Lieutenant-Governor and proceeded to act with all the assurance of accredited legislators for a new and thriving community. Appointed by the original *Act for the Temporary Government* merely to "aid the Lieutenant-Governor in the administration of affairs," [8] they were entrusted by the Act of 1875[9] with the duties of "advice and consent" which have always foreshadowed the historic development towards self-government. The Council became from the first not the recipients of special privileges but the exponents of local interests and rights as against the delinquencies of federal control. As such they had more than one occasion to protest against the ruinous delays of a distant administration. Matters of "urgent importance" were "permitted to remain altogether unnoticed for a period of six months." On December 4, 1874, the Council regretted that the Dominion Government had

> "not been pleased to communicate their approval or disapproval of the legislation and many resolutions adopted by Council at their Meetings held on the 4th, 8th, 11th and 13th of September, 1873, March 11th, 12th, 14th, 16th, 1874, and June 1st and

[7] Oliver, *The Canadian North-West*, p. 987; *Canada Gazette*, Nov. 15, 1873.

[8] "With such powers as may be from time to time conferred upon them by Order-in-Council," 32 and 33 Vic., c. 3, s. 4.

[9] Section 7.

2nd 1874, and they respectfully represent that such long delay has paralyzed the action of the Council." [10]

At the close of the purely conciliar period the Lieutenant-Governor was able to review the work of the Council with considerable gratification. By the *North-West Territories Act* of 1875 provision was made for a separate Lieutenant-Governor for the Territories and for an appointed Council of not more than five members, to be reinforced by elected members as soon as electoral districts of 1,000 square miles should be found to contain 1,000 adult inhabitants. When such elected representatives should come to number twenty-one,

> "the members so elected shall be constituted and designated as the Legislative Assembly of the North-West Territories, and all the powers of this Act vested in the Council shall be thenceforth vested in and exercisable by the said Legislative Assembly."

The second stage of the Canadian conciliar period (1876-1888) compares very favourably with the corresponding phase in the earlier colonies. There is no counterpart in Canada to the fatal policy of building up "the connection" with the mother country upon the basis of special privileges and vested interests. There is no American or French Revolution to palliate short-sighted policies of expediency. Nothing could be more conducive to the normal development towards self-government than the placid but exuberant growth of the West. The automatic development of the Council into an Assembly was not, it is true, a Canadian invention. It had already become a recognized British expedient, nowhere perhaps more usefully employed than in the case of British Columbia prior to Confederation. It served, however, to point the way to self-government, whereas the *Quebec Act* had been regarded by the American colonies—not unjustifiably—as "dangerous and destructive of American rights."

The problem was further simplified by the fact that the Territories were, of course, an integral part of the Dominion with ultimate provincial status as their manifest destiny. "The same constitution as the other provinces possessed would ultimately be conferred upon the country." [11] From the election of the first member of Council in 1881 to the culmination of the process in the election of twenty-two members in 1888, the development was swift and eventful. The collapse of the "boom," the less spectacular work of settlement, the building of the C.P.R., the Riel Rebellion, all fall within this period;

[10]Oliver, *The Canadian North-West*, p. 1031.

[11]Joseph Howe in *Recent Disturbances in the Red River Settlement*, 1870, p. 51.

and perhaps the most remarkable characteristic of the Council-Assembly is its continued solidarity for the West as against the exasperating delays and delinquencies of federal administration.

III. From Representative to Responsible Government

The stage from Assembly to responsible government in the North-West Territories is one of remarkable contrast with the colonial period of the original provinces of the Dominion.

In the earlier colonies the Legislative and Executive Councils were continued and deliberately reinforced; in some instances by special privileges and vested interests, in some by proposals (fortunately abortive) for hereditary titles, and in others by the Clergy Reserves from Crown lands for an established church. The contest between Council and Assembly for "responsible government" thus resolved itself into a contest between two sections of the same community, one exercising by virtue of appointment and the other claiming by virtue of popular election the control of administration.

In the Territories the old Council had been swallowed up and absorbed by the Assembly. There was no Family Compact. The *North-West Territories Act* of 1888 provided for an Advisory Council of four members on "matters of finance" to be chosen from the Assembly, together with *ex officio* legal advisers on matters of law; but the first act of the members of the Advisory Council was to align themselves not with the Lieutenant-Governor and the federal government but with the local Assembly in a carefully staged contest for fully responsible government.

Co-operation with the Assembly in this struggle was openly avowed by the Advisory Council on finance—"being with the rest of our fellow Members jealous of the rights, which were granted to us." Within a year the Advisory Council resigned in a body (Oct. 29, 1889) because they were "unwilling to accept responsibility without a corresponding right of control" over all "matters of finance," including not only territorial revenues but the annual subsidies from the Dominion. A new Advisory Council was promptly met in the Assembly by a sharp vote of want of confidence, and the result was a series of demands and concessions which culminated within nine years in practically full responsible government within the limits of the North-West Territories Acts.

The first of these contentions was that upon which the Advisory Council had resigned in 1889—the control of all financial resources, federal as well as local, at the disposal of the Crown under the Act.

The leaders in the Assembly, versed in the protracted struggle for similar powers in Nova Scotia, New Brunswick and the two Canadas, lost no time in stating their terms. They demanded not only the full estimates and accounts of both federal and local revenues, but that both should be "voted by the Assembly and expended by the Advisory Council."[12] Moreover, "the continuance in office of a Council not possessing the confidence of the Assembly was a gross violation of the rights and privileges of the Assembly."[13] The conflict that ensued was regarded by Assembly and press alike as a direct contest for responsible government, and it was prosecuted upon as high a level, perhaps, of courtesy and resolution as it would be possible to find among the score or more of similar contests in British communities all over the world. By the Act of 1891 (c. 22, s. 6, sub-sec. 12) the Assembly was at length granted control of "such portions of any moneys appropriated by Parliament for the Territories as the Lieutenant-Governor is authorized to expend by and with the advice of the Legislative Assembly or of any Committee thereof." In the following year Mr. Haultain proposed that "Parliament should vote a lump sum for the expenses of Government in the North-West Territories." The fiscal powers of the Assembly over this expenditure were at last complete. Lieutenant-Governor Royal, in the Speech from the Throne, September 16, 1893, complimented the Assembly upon their "wisdom and discretion." "Notwithstanding this controversy, no unpleasantness ever arose between me and the Assembly. . . . The Legislature to-day practically enjoys the rights and privileges of self-government."[14]

Meanwhile a second and more fundamental development was transforming the Advisory Council on "matters of finance" into an Executive Council entrusted with general administration and responsible to the Assembly. Here at least the Assembly pursued a headlong course which did not always command the support of sound opinion. The right to appoint the Advisory Committee on "matters of finance" was claimed by the Assembly, but the Minister of Justice, Sir John S. D. Thompson at that time, had no difficulty in showing that the ordinance to that effect (No. 24 of 1889) was *ultra vires.* The right was at length conceded by statute in 1894 (57 and 58 Vic., c. 17, s. 17), but when the Assembly sought to elect such a committee to advise *on all matters,* it was found that such a procedure would contravene one of the most valuable conventions of responsible government itself—the right of the Crown to choose its advisers.

[12]Oliver, *The Canadian North-West,* p. 1109.

[13]Resolution of North-West Legislature, Oliver, p. 1112.

[14]Oliver, *The Canadian North-West,* p. 1154.

The attempt to broaden the powers of the financial Committee by other cognate executive functions was only partially successful, and it was only in 1897 that provision was made by statute (60-61 Vic., c. 28) for an Executive Council "chosen and summoned by the Lieutenant-Governor . . . to aid and advise in the Government of the Territories." Within the limits of the Territories Acts the functions of such an Executive Council were now practically indistinguishable from those of the "Cabinet" in the government of the Province or of the Dominion.[15] The year 1897, therefore, may be said to mark the definite achievement of responsible government. The next stage of development was the broadening of the scope of territorial powers to the amplitude of provincial status.

IV. From Territories to Provinces

The achievement of provincial status for Alberta and Saskatchewan can scarcely be said to have passed into history, because, as Lord Rosebery wrote of the Irish Union, it "has never passed out of politics." This interplay of federal and local politics, and indeed much of the normal development towards provincial status itself, lies beyond the scope of this paper except insofar as Dominion policy has restricted or modified the normal practices of responsible government.

The restrictions of territorial status could be relied upon to force a change. As early as 1901, Premier Haultain submitted a draft bill for provincial organization to the federal government, though even then more generous financial terms might possibly have postponed the issue. The territories could not borrow money on the public credit; they could not charter companies with the amplitude of provincial powers. The direct administration of the Crown lands of the territories from Ottawa and the exemption from taxation in connection with the railway and other land grants strengthened the demand for the "control of the public domain in the West, by the West and for the West." With an assured prospect of provincial status in the end the analogy between the inadequate and variable grants from the Dominion to the territories and the fixed "legislative" and "per capita" subsidies to the provinces, pointed the way to similar "provincial terms" as the only escape from "financial necessity." In general, therefore, the *Alberta* and *Saskatchewan Acts* of 1905 were thus designed to accord the same rights and to impose the same responsibility which other provinces of the Dominion had taken for granted since 1867.

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[15]*Cf. Manitoba Act*, s. 7; *B.N.A. Act*, 1867, s. 11.

It remains, however, to record one very notable exception. The "colonial policy" of the Dominion with regard to Crown lands has departed so fundamentally from the normal procedure in British self-government that the contrast, even after the attainment of provincial status in other respects, remains exceptional and indeed unique.

The control of Crown lands, and particularly of the Clergy Reserves in Upper Canada, was not only one of the chief issues—perhaps the greatest single issue—forcing the demand for responsible government, but it constituted the first-fruits of that great reform. Self-governing communities which have relieved the Crown of the duties and responsibilities of direct administration have been entitled to the normal resources of the Crown for that purpose. As such, in a very peculiar sense, the public domain has been recognized from the earliest stages of colonial government; and "the plan adopted in every case of the grant of responsible government," as Keith points out, "took the form of a grant of full rights over the lands in exchange for a civil list." [16]

By the *Act of Union*, 1840, all land revenues were surrendered to the Assembly of "Canada" [17] and the administration of Crown lands followed as the first corollary of responsible government. The same procedure obtained in Nova Scotia, in New Brunswick, in Newfoundland, in New Zealand, in New South Wales, in Tasmania, in Queensland, in Victoria, in South Australia and in Western Australia, both before and after the Australian confederation.

The provincial control of Crown lands was confirmed in both the Canadian and Australian confederations—by sections 92 and 109 of the *B.N.A. Act* of 1867 and section 107 of the *Commonwealth Act* of 1900. In the case of British Columbia, which entered Confederation in 1871, the same provincial rights were taken for granted without discussion on either side. In the case of Prince Edward Island, in 1873, the Dominion went so far in pursuance of the same principles as to compensate the Island by an annual subsidy for lands alienated by royal grant nearly a century before responsible government was conceded overseas.[18]

As already suggested, the reasons why similar provincial rights were not accorded to Alberta and Saskatchewan in 1905 have "never

[16]Keith, *Responsible Government in the Dominions*, ii, 1047.

[17]3 and 4 Vic., c. 35, s. 54.

[18]The sum of $800,000 was also to be loaned to P.E.I., as required, to purchase the lands of absentee proprietors, for re-sale to small holders. See Chester Martin, *The Natural Resources Question*, 1920, King's Printer, Manitoba, cc. v and vi.

passed into history," but it will be sufficient to observe that the prairie provinces of Canada constitute, as far as I know, the only exceptions among the self-governing provinces and Dominions of the British Commonwealth to this fundamental practice of responsible government. Even in the case of the prairie provinces, the so-called "subsidy in lieu of lands" was regarded, even by Sir Wilfrid Laurier, as confirming rather than supplanting this "guiding principle"[19] of responsible government and of Confederation; and one of the members of the Judicial Committee of the Privy Council recently expressed some astonishment at the survival of this constitutional anomaly.

With regard to public lands, therefore, the "colonial policy" of the Dominion has been, in some respects, more reactionary than that of George III with regard to the old province of Quebec. More than 20,000,000 acres of lands in Manitoba have been alienated from provincial control. Over six million acres in Alberta were granted to railway companies for the construction of railways in other provinces. In this respect, at least, Manitoba since 1870 and Saskatchewan and Alberta since 1905 have been not provinces but "colonies" of the Dominion.

The achievement of responsible government in the Canadian territories confirms the reflection that this most fundamental of all British processes of government has been the result of the cumulative wisdom of experience. In the original experiment the issue was defined for the first time only at the Grand Remonstrance of 1641, after nearly 400 years of parliamentary development. It was solved only after another century and a half, by empirical methods so gradual in their operation that even in the early nineteenth century the process had scarcely been reduced to a body of political doctrine.

The same fundamental problem emerged, as it was bound to emerge, in the American colonies after more than 100 years of representative institutions; though even Chatham and Burke seem to have recognized only its incipient stages. The same problem came to an issue upon Canadian soil less than fifty years after the granting of an Assembly by the *Constitutional Act.* The issue might have arisen even more promptly had the war of 1812 not interrupted the process.

In the Canadian territories the problem was stated within nine months and effectually solved within nine years of the meeting of a

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[19]Sir Wilfrid Laurier to Hon. A. L. Sifton, Aug. 7, 1911.

Legislative Assembly. This may not be the speediest but it would seem to be one of the least unpleasant of more than a score of similar experiments in which British communities all over the world have sought similar constitutional rights.

Much of the success may have been due to conditions peculiarly favourable for the solution of a problem at once so practical and so urgent. Much was undoubtedly due to statesmanship of a high order in so primitive a community. The work was done by men of downright courage and optimism versed in the sovereign wisdom of historical as well as political experience. The real objects for which they contended have never been—and by their very nature can scarcely be—committed to the statute or the Order-in-Council. Responsible government is an unwritten thing, or rather not a thing at all but a method. In that sense the most important elements of our Canadian "constitutions," both federal and provincial, are not "written" at all. Section 9 of the *B.N.A. Act* of 1867, for instance, provides that the executive government shall "continue and be vested in the Queen." Similarly section 7 of the *Manitoba Act* provides that "the Executive Council shall be composed of such persons, and under such designations, as the Lieutenant-Governor shall, from time to time, think fit." Behind both sections lie two centuries of history and convention from Pym to Elgin and Joseph Howe. Without that history and that convention the letter of these Acts would mean exactly the reverse of the actual practice. The spirit is to be sought not in the letter of the Act but in the study of constitutional history. That of Canada is rich beyond all present computation, and the march of events seems to indicate that it is coming at last into its own.

The Raison d'Etre of Forts Yale and Hope

BY HIS HONOUR JUDGE F. W. HOWAY, LL.B., F.R.S.C.

(Read May Meeting, 1922)

The traveller upon the Canadian Pacific Railway, on emerging from the gloomy gorge of the Fraser canyons, finds the mountains receding as the train turns to the westward. He is at Yale. Enquiry elicits the information that, though now a typical Sleepy Hollow where life moves slowly and grass grows in the only street, it was originally a trading post of the Hudson's Bay Company. Twelve or thirteen miles further he passes another abandoned establishment of that company. The question at once naturally arises: Why were two trading posts built by the same company so near to each other? This paper is an effort to afford the answer.

Until the North West Company purchased Astoria in 1813 the goods for, and the produce of, its posts west of the Rocky Mountains were transported along the regular route from and to Montreal. After that purchase, by which they obtained complete control of the Columbia River region, a ship was despatched annually to Astoria, then known as Fort George, with the necessary trading goods.[1] Having discharged her cargo the vessel took on board the furs collected by the river forts and continued her voyage to China. It is clear that the trade connection between these forts and the central depot was along the natural line—the river. But as regards the Thompson River and New Caledonia divisions it seems probable that the old route to Montreal continued during all the days of the Nor'Westers.[2] Alexander Ross records that in 1814 a scheme for diverting the trade routes of these two sections into the channel of the Columbia was arranged;[3] but it would appear that it never came into operation. Harmon does, indeed, mention the arrival, at Fort St. James in October, 1814, of Mr. La Roque from the Columbia with "two canoes laden with goods;" [4] but this seems a mere isolated venture. Scattered allusions, however, show that regular communication by *express*

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[1]See hereon generally: Correspondence of the Foreign Office and of the Hudson's Bay Company, Ottawa, 1899, part ii, p. 10.

[2]Harmon's Journal, Andover, 1820. Entry of November 7, 1818, pp. 268-9; and in the New York reprint, 1903, p. 229.

[3]Alexander Ross, Fur Hunters of the Far West, London, 1855, vol. I, p. 73.

[4]Harmon's Journal, 1820, ed. p. 242; 1903, ed. p. 204.

existed between New Caledonia and Astoria.[5] Other entries, nevertheless, indicate that the line of trade continued to lead across the mountains.

After the union of the North West and the Hudson's Bay companies in 1821, Governor Simpson found himself so busy with the adjustment of affairs east of the Rocky Mountains that it was not until October, 1824, that he was able to give his personal attention to the Pacific slope.[6] It is said that he had already considered the possibility of a shorter route for the trade of New Caledonia, and that in 1822 John McLeod had made, by his instructions, an attempt to find an outlet by way of the Fraser River.[7] Such a route had been often discussed; in 1814 Ross had made an unsuccessful effort to find it;[8] and when Simpson arrived he had to face his transportation problems on the basis of the Columbia's being the only available way. It is not intended to deal with the adjustments then made; it is sufficient that he reorganized the transport service and decreed that the goods for Thompson River and New Caledonia should be taken by bateaux up the Columbia to Fort Okanagan at the mouth of the Okanagan River, thence overland to Kamloops and on to Fort Alexandria, there to be retransferred into bateaux for their different destinations.[9] The produce of the region was to come out over the same route. Setting out from the furthermost posts of New Caledonia in June, the brigade, as this transport was called, grew in volume as it gathered the returns from other forts. On leaving Alexandria, where the land travel commenced, it comprised probably more than two hundred horses; Kamloops added the quota of the Thompson River district, and the brigade continued to Okanagan where the water carriage was resumed.

The connection between Alexandria and Okanagan was known as the brigade trail; it was a line as definite as any road of to-day; and the brigade travelled along it, as along the whole route, upon a

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[5]Harmon's Journal, 1820, ed. p. 240; 1903, ed. p. 202; entry of April 17, 1814.

[6]The Quarterly of the Oregon Historical Society, vol. xi, pp. 246-7, containing an article upon Peter Skene Ogden by T. C. Elliott.

[7]See an address by Sir Sanford Fleming in the Transactions of the Royal Society of Canada, 1889, pp. 113-114. And see also Journals and Correspondence of John McLeod in the Department of Archives, Ottawa.

[8]Alexander Ross, Fur Hunters of the Far West, vol. I, p. 42 *et seq.*

[9]See John Work's Journal in Washington Historical Quarterly, vol. v, p. 284 *et seq.* At the General Council at York Factory on 2nd July, 1825, the following resolution was adopted: "20. New Caledonia Returns next Spring to be taken to Fort Vancouver and receive there the Outfit for 1826."

regular schedule. "A beautiful sight," says Malcolm McLeod, "was that horse brigade, with no broken hacks in the train, but every animal in his full beauty of form and colour, and all so tractable—more tractable than anything I ever knew of in civilized life." [10] At Okanagan the brigade was joined by the bateaux from Fort Colvile, carrying the returns from the upper Columbia and the Kootenay. This route became effective in 1826,[11] and from that time "the brigade," "the arrival of the brigade," and "the brigade trail" are expressions found constantly in the records of New Caledonia.

So for twenty years the trade ran along. In the meantime the Oregon Question had arisen and developed into a heated subject of discussion. The company had, as early as 1825, officially informed Dr. McLaughlin "that in no event could the British claim extend south of the Columbia;" [12] but it soon became evident that the boundary would in all probability be drawn much further north. This meant that Fort Vancouver, its headquarters, would fall within American territory; hence the determination to establish Fort Victoria. The minutes of the meeting at Norway House in 1842 record with charming generality: "It being considered in many points of view expedient to form a Depot at the Southern end of Vancouver's Island it is Resolved that an eligible site for such a Depot be selected and that measures be adopted for forming this Establishment with the least possible delay." [13] In the following year the entry runs: "That the New Establishment to be formed on the Straits of Fuca to be named Fort Victoria be erected on a scale sufficiently extensive to answer the purposes of the Depot; the square of the Fort to be not less than 150 yards; the buildings to be substantial and erected as far apart as the grounds may admit with a view to guarding against fire." [14] Fort Victoria was accordingly built in 1843.

The Oregon Question, after having brought the two countries to the brink of war, was settled by the Treaty of Washington, 1846. Having in view the existing route of the company a provision was inserted that the navigation of the Columbia from the 49th parallel

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[10]Peace River; A Canoe Voyage, etc., by Malcolm McLeod, Ottawa, 1872, p. 114.

[11]Peace River, p. 93; and see a note by T. C. Elliott appended to Work's Journal in Washington Historical Quarterly, vol. v, p. 101.

[12]Document Found Among the Papers of the Late Dr. John McLaughlin and published in the Transactions of Oregon Pioneer Association, 1880; The Acquisition of Oregon, by William I. Marshall, Seattle, 1911, vol. i, pp. 166-7.

[13]The Canadian North-West, edited by E. H. Oliver, Ottawa, 1915, vol. ii, p. 846.

[14]The Canadian North-West, vol. ii, p. 862.

to the Pacific Ocean "shall be free and open to the Hudson's Bay Company and to all British subjects trading with the same" and that in the exercise of that right they should "be treated on the same footing as citizens of the United States." [15]

Before the treaty was negotiated Alexander Caulfield Anderson, then stationed at Fort Alexandria in New Caledonia, realized, as did many others, that the boundary line would probably be drawn along the 49th parallel. "I judged it prudent, therefore," he writes in his manuscript History of the Northwest Coast, "to endeavour to provide beforehand some route of access to the sea which might supplement, and perhaps eventually supersede, our usual route of communication, via the Columbia River, with the depot at Fort Vancouver. I accordingly wrote to the Governor (Sir George Simpson) in Council at Norway House, near Winnipeg, and requested to be allowed, for the reasons stated, to explore a route to Fort Langley on the lower Fraser through a tract of country at that time practically unknown."

Mr. Anderson's proposal was accepted by the Governor. It does not appear to have been submitted to Council, for Peter Skene Ogden, writing from Colvile on 22nd October, 1845, to Messrs. Tod and Manson, says: "Shortly prior to my departure from Red River[16] Sir George Simpson suggested to me that it would be most highly important to ascertain if a communication with horses could be effected between Alexandria and Langley and as Mr. A. C. Anderson has volunteered his services and from his active habits and experience in Caledonia I consider him fully competent to carry it into effect, I have to request that he may be appointed." [17] While not limiting Anderson's freedom of action, Ogden suggested that the westward journey should be by way of the chain of lakes from Lillooet to Harrison River, and the return by the canyons of the Fraser River. The letter shows that the Hudson's Bay Company had even then a good knowledge of that part of the province. How this was obtained it is difficult to say; for from the time of Fraser's voyage in 1808 we have no record of another visit to that vicinity except the express canoe journey of Governor Simpson in 1828; and neither of these travellers left the river or stayed to examine the country. The information may have been obtained from the natives; though in that case it is unusually correct.

[15]Treaty of Washington, June 15, 1846, article II.

[16]Ogden had just returned from England. He was accompanied by Messrs. Warre and Vavasour. Father De Smet, in a letter dated 17th August, 1845, describes his meeting with the party on the Kootenay River; see Missions de l'Oregon, Gand, 1848, pp. 72-3.

[17]Letter preserved in the Archives of British Columbia.

Anderson set out in May, 1846, with five companions, taking the course that had been indicated and living on the country as Ogden had ordered. The journey outward occupied nine days; the distance was estimated to be 229½ miles. He unhesitatingly condemned it as altogether useless for the company's purposes. On his return trip, instead of examining the Fraser canyons, he left that river at what is now the town of Hope, taking his course up the defile of the Coquahalla, across the Cascade Mountains to the Tulameen River, and over the plain country to Kamloops. The whole return journey from Langley consumed thirteen days. In his report[18] Anderson stated that a practicable road might be made by that route, but owing to the elevation of the summit it would only be available for the passage of the brigade between the months of July and September.

James Douglas, the head of the company on the Pacific coast, did not favour such a location, with its narrow time limitations, for the connections with the interior. He clung to the belief that a suitable road could be obtained by travelling west from Kamloops along or near the Thompson River, and, after crossing the Cascades, descending to the Fraser in the neighbourhood of Spuzzum. On January 12, 1847, while formally approving and commending the zeal of Mr. Anderson, and condemning the Coquahalla route because of its elevation, he instructed him to examine the possibility of finding a passable trail for the brigade upon the general line above indicated. Accordingly in May, 1847, Anderson and five companions departed once more from Kamloops following now the south side of the Thompson River, but he soon decided that no practicable route could be found in its valley. He, however, discovered further to the southward a suitable line by which Fraser River could be reached at the spot mentioned by Douglas. This trail followed in a general way up the Coldwater River, across the Cascades, and, after proceeding along Anderson River for a distance, turned to the left and reached the Fraser at Kequeloose, about six miles above Spuzzum, and near the site where the suspension bridge was afterwards erected. From that point he had to face the stretch of two or three miles of bad water, the lower canyon of the Fraser. Though the river was then in freshet, Anderson concluded that by portaging at three spots it could be utilized for the conveyance of both the goods and the furs. To assure himself on this essential point he proceeded to Langley, resolving on his return trip to bring a canoe thence to the head of the lower canyon. He left Langley on 1st June and in five days, with some mishaps, succeeded in his purpose. This, however, as he well realized, proved but little;

[18]Report of A. C. Anderson preserved in Archives of British Columbia.

there is an immense difference between the navigation of a light canoe and the navigation of a heavily laden bateau against the Fraser at its mid-June height.[19] In his report 21st June, 1847, he expressed the opinion that "the series of rapids in the vicinity of the Falls (*i.e.*, the lower canyon) extending with intervals of smooth water in all from 2 to 3 miles presents no insurmountable impediment to our progress from the facility of making portages if found necessary, as they doubtless will be, at the higher stages of the water." For the purpose of avoiding the worst of the freshet he suggested that the brigade should so time its movements as to reach Langley about 20th June. "It is difficult," he says, "to realize a conception of the ruggedness of the extraordinary region without actual observation. One is surprised rather at finding any practicable passage than disappointed at the reverse." This calls to mind Fraser's vivid description of the same locality. As though he foresaw the disturbing events which were soon to occur on the Columbia and imperiously require the immediate adoption of this route, Anderson, before departing for Alexandria, furnished the Indians with the necessary implements to construct a trail for horses across the Cascades to the Fraser at the point where he had left his canoe.

Douglas, however, was cautious. He determined, in company with J. M. Yale and William Sinclair, personally to examine this stretch of dangerous water in the summer of 1847. His report was decidedly adverse. That section, he said, "will be found exceedingly dangerous at every season and absolutely impassable in the summer freshets when the river is full and attains a level of 60 feet above the low water mark in autumn. The rapids," he continues, "occur at a spot where Fraser's River forces a passage through the Cascade Mountains and stretch from side to side of that stupendous barrier. It is impossible to conceive anything more formidable or imposing than is to be found in that dangerous defile, which cannot for a moment be thought of as a practicable water communication for the transport of valuable property." Clinging tenaciously to his view that a passable road could be made, Douglas, while condemning utterly the water route through the little canyon which Anderson had thought feasible, substituted a cumbrous scheme of ferrying horses and goods and furs across the angry Fraser at Spuzzum and making a trail of about thirteen miles to the spot afterwards known as Fort Yale. Of it he wrote: "This extension of the horse road must be carried through the mountains in a narrow winding defile on the north side of Fraser's River, which runs nearly parallel with it. Though neither

[19]Report of A. C. Anderson preserved in the Archives of British Columbia.

smooth nor level it is practicable and, when the timber is cleared away, will make a much better road than we expected to find in so rugged a section of country. It has, moreover, the important advantage of being safe, and is infinitely preferable to the most perilous piece of water communication in the Indian country." [20]

In the year and a half which had elapsed since the Treaty of Washington, the Hudson's Bay Company had keenly felt the animus existing against it in the minds of the Americans, and had found to its cost, that the right to navigate the Columbia "on the same footing as citizens of the United States" was quite illusory in practice, however valuable it might appear in the abstract. The goods for New Caledonia were imported with the other goods and delivered at Fort Vancouver. They were, therefore, subject to duty. In urging celerity in the effort to find and open a road to the coast by way of the Fraser, Douglas wrote on 6th November, 1847: "We will thereby escape the exactions of the United States Government and have it in our power to supply the interior with British goods free of import or transit duties." His intention then was to have the road built in time to enable the brigade of 1849 to utilize it.

But within three weeks thereafter occurred the destruction of the mission station at Wai-i-lat-pu, near Walla Walla. The Indians on that occasion, which is commonly called the Whitman massacre, murdered Dr. Whitman and thirteen others. Out of this massacre arose the Cayuse War of 1848 in Oregon. The effect of this strife was, of course, to close the Columbia River to the peaceful trader. The usual road being thus blocked, the company was, of necessity, compelled to alter its plans and to adopt immediately the Fraser River route. How far this compulsion reacted disastrously upon the new venture it is now impossible to estimate. Anderson records that in the early part of 1848 an express arrived from the headquarters at Fort Vancouver detailing these events and ordering that the brigade of 1848 break its way at all hazards through to Langley, whither the supplies for New Caledonia, Thompson River, and Colvile would be forwarded.[21] The Cayuse War, however, only hastened the advent of the inevitable; for with the removal of the company's headquarters from Fort Vancouver to Fort Victoria (which took place in 1849) the abandonment of the Columbia River route for a more northerly one must of necessity occur.

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[20]Letter in the Archives of British Columbia.

[21]Anderson's manuscript History of the North West Coast, copy in the Archives of British Columbia.

Early in the spring of 1848 (though the exact date is uncertain) a small unstockaded post called Fort Yale, in honour of that courageous little man, James Murray Yale, Chief Trader, was erected at the end of the "horse road" near the Indian village below the little canyon. This establishment, while not neglecting an opportunity of obtaining furs, was intended primarily as an adjunct of the new scheme of transportation. It was to fulfil the same duty on the Fraser route that Fort Okanagan had fulfilled on the Columbia route. At the same time bateaux capable, like those on the Columbia, of carrying about three tons each, were built at Langley to convey the trading goods to Yale, where they were to be exchanged for the furs brought out by the brigade. Simultaneously the trail across the Cascades to Fraser River and along the detour from Spuzzum to Yale, which Anderson calls the Douglas Portage, was hastened to completion.

In June, 1848, the attempt was made. The three brigades, from New Caledonia, Thompson River, and Colvile respectively, numbering fifty men and four hundred horses, were despatched in command of Donald Manson and A. C. Anderson. After much difficulty and many dangers—for a considerable number of the animals were unbroken—the brigade reached the Fraser. The task of getting four hundred horses and their lading across the swiftly-flowing, freshet-swollen river on this pioneering effort was indeed downheartening. It was, however, accomplished and in due course the brigade reached Yale. The bateaux, after eight days of terrific struggle against the heavy current—in part of which progress could only be made by towing with tump lines and pushing with poles—also reached the rendezvous. Their return was easy in the last degree; the rapid current became their friend and carried them quickly back to Langley. But the horse brigade had, on its return, to face its most difficult task. The trading goods were bulky and more perishable than the furs. Large quantities of the merchandise were stolen by the natives, who had gathered in the canyon for the annual fishing; many of the horses were lost in crossing the river. So disheartened were the *engagés* that one of them committed suicide; his grave was, even in the early days of the gold rush, ten years later, a well-marked, well-known spot.

Anderson's report is eloquent: "As regards the route we have stumbled through this year with its concomitant circumstances, I believe you will agree with me in condemning as quite unsuited to the views of the Concern. The question of navigation as far as Kequeloose (Suspension Bridge) where I last year proposed the horse transport to commence being negatived the whole scheme of communication thence depending necessarily falls to the ground. The prudence, not to say possibility, of extending our horse transport beyond that point has this year been fully tested and needs no comment on my part.

"As regards the question of navigation my opinions have undergone some change, for though, as before, I think it practicable to bring up Columbia boats by making the necessary portages, further examination teaches me that it must be by very arduous degrees at the higher stages of the water and therefore unadvisable. At low water, however, the rapids have been proved to be safely navigable with loaded bateaux one portage only intervening. These points admitted I am still constrained reluctantly to withdraw the proposal of navigation formerly advanced by me. My recent experience of the pass in question convinces me that no portage on a large scale could with prudence be effected there during the summer season, after the hosts of barbarians amongst whom we have recently passed are engaged at their fisheries.

"The risks of sacrificing both life and property (for it is needless to attempt to cloak the matter) under circumstances where neither courage nor precaution could avail to resist surprise or guard against treachery are alone sufficient to deter us from the attempt. The losses by theft, in themselves no wise contemptible, which have already taken place are but the prelude to future depredations on a larger scale should the present system of operations be unfortunately persisted in—depredations which it is to be feared will be difficult either to discover in time or prevent effectually." [22]

This one trial trip satisfied Douglas that such a road with its requirements of ferrying and its dangers not only of the route itself, but also of the natives, was quite impracticable and he reluctantly, it would appear, fell back upon a route via the Coquahalla. In the summer of 1847 Mr. Yale had sent Mr. Peers to examine that region once more. By making some alterations in the line as explored and recommended by Mr. Anderson in 1846 he had found that the snow, which was the one adverse factor, was not so formidable as had been anticipated. Mr. Anderson strongly advocated the adoption of this route for the brigade of 1849.

In the fall of 1848, Douglas finally gave orders for the erection of Fort Hope at the mouth of the Coquahalla and for the opening of a trail up that river and across the Cascade Mountains. Those letters are so important that they are appended hereto. They show the circumspection with which the company always moved; if the attempt

[22]Anderson's report, copy in the Archives of British Columbia.

of 1848 be regarded as an exception, it must be remembered that the company had been forced by circumstances to act without delay.

The trading post—Fort Hope—was built; but despite the utmost efforts the road was not sufficiently advanced to admit of the brigade's being brought out over it in the spring of 1849; in consequence, the terrible route by way of the canyons and Yale with its ferry and its detour was utilized. "Its difficulties," says Anderson most modestly, "were too harassing." On the return of the bateaux from Langley, instead of proceeding to Yale, they stopped at the new fort, Hope. There the whole party set to work to finish the trail so as to enable the horse brigade, which had returned light from Fort Yale, to reach Fort Hope and transport thence the trading goods that had been brought up by the bateaux.[23] This was the end of Fort Yale, as a factor in the company's transportation system, which, as has been shown, was its only *raison d'être*. It did, it is true, revive for a few years during the golden days of the Fraser and of Cariboo, but by that time the Hudson's Bay Company had ceased to be a power in the land. Fort Hope grew up and waxed great, not as a trading post, for it was never in that class, but as the *terminus ad quem* of the horse brigade and the *terminus a quo* of the bateaux. In 1850, as another letter which is attached as an appendix hereto shows, the express service of the company was directed through Fort Hope. So from the day of its construction until the glory of the company had departed, each June saw Hope one of the busiest places in the company's whole system as the annual brigade arrived with its furs and departed with its trading goods.

[23]Anderson's manuscript History of North West Coast.

APPENDIX

Fort Langley, 30th Oct., 1848.

John Tod, Esq.

Dear Sir:—

Having met Mr. Peers on the Cowlitz Portage, I received your letter of the 25th Aug., which will meet with due attention hereafter, on my return to Fort Vancouver, and your various demands for assistance be complied with as far as our means permit. My object in addressing you from this place chiefly is to put you in possession of our views and the plan we have in contemplation with respect to the communication with the Interior. In consequence of the very unfavourable report we have received from Messrs. Manson and Anderson of their last summer's route we have come to the determination of opening a new road recommended by Mr. Peers after a very careful survey. Leaving Fraser's River it follows successively the valleys of the Quequealla, Peers, and the Soaqua Rivers, from thence the crossing of the dividing ridge into the Similkameen Valley, where it falls upon Mr. Anderson's track of 1846 and follows it to Thompson's River. Mr. Peers will be despatched with ten men in a few days hence to commence operations at the mouth of the Quequealla, where we intend to establish a small Post for the convenience of parties passing to and from Thompson's River and at the same time he will proceed in opening the road with the assistance of all the Indians that can be mustered, and we hope to have it made as far as the snowy region before the winter sets in. The more elevated parts must be left until the disappearance of the snow in the spring and the first weeks of summer when I trust this important undertaking will be completed. This road will not be accessible for horses before the beginning of July and can only be considered in the light of a temporary expedient for the transport of the Interior Outfits until our posts are withdrawn from the Columbia, and were it not for the extreme reluctance of Mr. Manson to continue the route of last summer we would not have gone to the expense of opening a new Road which in many respects will be found exceedingly inconvenient. We have directed Mr. Peers to use every exertion to communicate with you, either by means of Indians or otherwise, in order that you may co-operate in the important service on which he is now employed and give him every assistance in your power. He has instructions to apply to you for guides and such other aids as he may stand in need of and I have most earnestly to request a compliance with his demands.

He is particularly desirous that Blackeye's son, the Indian who accompanied him a part of the way on his late journey to this place and left him at the head of the Soaqua, should be sent to meet him at that point, as without such assistance he will not be able to find his way into the Similkameen Valley, by the proper route, with that Indian you will please despatch Montigny and as many whites and Indians as you can muster to open the road from the plains of the Similkameen to the Soaqua Valley following the line of road Mr. Peers pointed out to Montigny as being the best adapted for horse-transport, as early in the spring as the snow will admit; an arrangement which will greatly expedite the work and enable us to complete it in time for the brigade of 1849. Leaving all these matters in your hands and trusting that you will suggest the ways and means of carrying them most rapidly into effect

I remain,

Yours truly,

JAMES DOUGLAS.

Fort Langley, 30th October, 1848.

James M. Yale, Esq.

Dear Sir:—

Having conferred with you very fully on the plans contemplated for the coming year, both as respects the general arrangements of the business and the special arrangements connected with the communication to the Interior, I will in this note merely give a general summary of these, as a memorandum for mutual reference.

Mr. Peers having been detached by Mr. Manson from the establishment under his command to survey and open a new route for the brigade to Thompson's River, in consequence of the road by Kequeloose being considered in many respects inconvenient and dangerous, we have determined on carrying Mr. Manson's views as soon as possible into effect by employing Mr. Peers during the approaching winter and spring in opening the road he lately explored, which appears by his chart to pass successively through the valleys of the Quequealla, Peers, and the So-au-qua Rivers, from the latter stream into the valley of the Shemilkomeen and from thence through the Plain country to Thompsons River. For the execution of that important service you will have Mr. Peers and ten men, who are to be despatched as soon as the necessary arrangements can be made, to select a convenient spot near the mouth of the Quequealla for a small establishment surrounded with stockades to consist of a dwelling house and two stores, which will be requisite for the accommodation of the Brigades passing and repassing to the Interior. It is not expected that the establishment will be completed during the present winter, as the labour of opening the road and levelling it with the spade will be severe and occupy much time. I would therefore recommend that our own men, and as many Indians as can be induced to assist, should be employed upon the road, whenever the services of the former can be spared from the duties of the establishment; and the latter may be engaged to commence operations as soon as Mr. Peers reaches the Quequealla. The road is after all the main object and we trust it will be completely opened by the time the snow is sufficiently melted next summer to permit the passage of the Brigade, which will probably occur about the beginning of the month of July.

Mr. Peers will endeavour to communicate during the winter or spring with the officer in charge of Fort Kamloops—in order that he may be made acquainted with our plans—the progress made in opening the road, and have an opportunity of co-operating from the other side of the range of mountains and of furnishing every assistance in his power to advance that important object. I have now written Mr. Tod to send an Indian guide to meet Mr. Peers on the So-au-qua, and to conduct him from thence by the best route into the Shimilkameen Valley, a part of the road which is better known to the Shooshwaps, than to the Indians of Fraser's River. As soon as the road is finished Mr. Peers will proceed with two or three men to meet the Brigade in order to conduct it to the Banks of the Fraser's River. The Interior Outfits will be sent from Fort Victoria in the spring and may be forwarded in whole or in part to the establishment at the Quequealla, provided the Indians in that neighbourhood evince no unfriendliness of disposition, and you think the goods may be left there without any risk, on the contrary let every thing remain in store here until the arrival of the Brigade. Were it in our power to forward the entire outfit to the establishment above, it would be a great saving of time to the Interior Brigade, but while duly estimating the importance of that object, we must not overlook the more important consideration of preventing difficulties with the Indians—which more than any other cause are likely to proceed from a rash confidence in their honesty, and forbearance. I therefore advise you to be very cautious and not to excite their cupidity by leaving too much in their power.

With respect to the general business of the Post I've nothing to suggest or recommend, by way of amelioration on the system which is now in successful operation.

From the present state of the foreign market and the quantity of salt fish on hand, I do not think that we will be able to export with advantage more than 1,000 barrels of salmon next year, and you will shape your arrangements accordingly.

With best wishes,

Yours truly,

James Douglas.

Private.

Fort Victoria,
18th March, 1850.
Ans. 30th April.

A. C. Anderson, Esqre.

My dear Sir:—

I give this a chance, by a conveyance, intended to test the Fort Hope road, at this season; with the view of making use of it hereafter for the Express; there being so many hinderances by the Columbia, that it is highly desirable to have another string to our bow, to use as occasion may require. Our present intention is to despatch a packet from this place, on or before the 19th Proximo which Yale will forward as soon as possible after it reaches Fort Langley, and should it arrive at Colvile in time to catch the Express from Vancouver, we may consider the question settled to our entire satisfaction, as the next attempt will probably succeed better than the present. The greatest difficulty will be the transport of the Paper Trunk, with passengers, baggage and the provisions required for the large parties which sometimes go out in Spring; but after a few journeys to and fro, even that difficulty will cease to be regarded with dismay.

The brigades are to meet at Thompson's River this Spring about the usual date, and if you are not there with the Colvile people in time Manson is at liberty to go on to Langley without you. He was altogether too late last year for the business of New Caledonia. We have taken measures to prevent the like occurrences this season by authorizing him to proceed from Thompson's River with or without the Colvile people. I should infinitely prefer your travelling in

Company, but if that cannot be accomplished without inconvenience, why there is nothing in the character of the road or state of the Indians to hinder the march of the Interior Brigades to the Depot in separate divisions. There is a strong impression on my mind, that the mountains between the Horseguard and Fort Hope, will be found impassable for horses, until the snow is nearly all gone, though many experienced persons are of a different opinion and suppose the snow will be compact enough to support loaded horses. If not we shall be in a manner forced to resort to the Kequeloose road, for the outcoming Brigade; as the final alternative to establish a Depot for the interior at Fort Hope, which the Brigades may always manage to reach by the 10th and leave by the 25th of July, a season sufficiently early for their return in good time. The reasons for and against these plans will occur to your own mind, except perhaps the present scarcity of men and difficulty of procuring recruits, to perform the transport from Langley—and other indispensable Depot work which is now done by the Interior men. I think that difficulty will prove fatal to any attempt to relieve the interior of any part of the transport work, without taking into consideration the heavy expense it will bring upon the trade, in maintaining an extra number of men to attend to it.

Enough on that subject for the present, let us turn to something else. The winter has been rather more severe than usual in this quarter; but we are now making rapid strides towards a more genial season. The California excitement continues as strong as ever, in this quarter, to the great injury of the country. The benefit derived from the gold discovery is confined to the few, the detriment to the million. A great part of the city of San Francisco was lately destroyed by fire and the city of Sacramento was laid waste by water, the site being below the high water level of the River. A scarcity was apprehended in that country but provisions are now abundant and cheap.

Her Majesty's Sloop "*Driver*" arrived here on the 11th inst. with His Excellency Richard Blanshard, Esqre., Governor of Vancouver Island, on board. Mr. Blanshard has neither Secretary nor Troops, being accompanied by a single body servant. I have not had time to become much acquainted, but I may say that his quiet gentlemanly manner is prepossessing.

He has not yet entered upon his Executive duties, further than reading his Commission to the assembled states of the Colony. Capt. Grant is still the only colonist upon the Island. Dodd, Sangster, and other parties in the Company's service, wish to become settlers; but are scared at the high price charged for land say £1 Sterling per acre.

I hope you will think differently on the subject. For my own part I am resolved to hesitate no longer, but to make a purchase as soon as possible. I would rather pay a pound an acre for land with a secure title and numerous other advantages than have a farm for nothing with 10 years torturing suspense. The Barque "*Cowlitz*" from England arrived here a few days ago, and we are now busy discharging her cargo.

Nearly all the seamen on board ran from her at the Sandwich Islands from whence she came on with Sandwich Islanders, who made a shift to get here, but cannot be trusted on a coasting voyage.

This is not our only difficulty, two more ships are expected out in course of this season, with about 70 servant Colonists, whom we shall have trouble enough to keep and feed. The anxiety and suspense of this life is torturing, wealth is truly no compensation, except it leave one at liberty to seek a change. Beaver is still as low as ever, the 1st June Dividend was £87..0..0 per 1/85-; but something better must come in December. The school is prospering, but not numerously attended—6 boys and 11 girls is all the force we can yet muster. The children are boarding with Mr. Staines, who is very kind to them, they are not so well accommodated as I wish, but we shall go on improving. Pray let me know when this gets to Colvile, it being a trial trip. All unite with me in kind respects to Mrs. Anderson and Eliza—with best wishes.

My dear Sir

Yours truly

JAMES DOUGLAS.

Lieutenant-General Garret Fisher: A Forgotten Loyalist

By W. D. LIGHTHALL, M.A., LL.D., F.R.S.C.

(Read May Meeting, 1922)

Lieutenant-General Garret Fisher does not appear in any of the lists of Loyalists of the American Revolution; his name and deeds are now never mentioned unless perchance by occasional delvers in the rarest corners of the history of old New York, or by one or two historians of certain British regiments, or in the obscurest genealogies of a few historical families. Yet in his day and generation he occupied a place of considerable prominence, was a man of wealth, standing, high connections and heroic personal record, and was the Loyalist who attained the highest military rank. He was forgotten principally because he left no direct descendants, and his representatives were far from the scenes of his life. It has, therefore, appeared to the writer to be a duty as one of his collateral descendants, and as one who, though distant, owes something to his record and estate, to resuscitate his memory, so far as may be, in a sketch of his career. In my childhood certain interesting historical names were repeated from time to time in our family circle, and among the others that of the collateral ancestor whose fortune had contributed a certain share to their immediate position. It was his money which had built, in 1825, the beautiful house near Lacolle called "Rockliffe Wood," which I knew as the family centre; parts of his armorial silver were treasured there and from it was assumed the coat-of-arms borne by my father; parts of his uniforms and other personal articles were among those of a similar kind there possessed; the large-type original orders relating his battle honours, though lost, were remembered; his great gold "turnip" of a watch had been worn and traded away by an uncle in his youth; his fine old oil portrait and miniature were described and traced to distant relatives; the events of the coming of his fortune from England in 1812 were romantically told, lawsuits concerning it were the subject of many confused references; it was persistently stated that the scene of his chief military honours was the Island of Guadaloupe; and it was erroneously alleged by one that he was a colonel of Grenadier Guards having the honorary rank of general, and by another, that he was an admiral, possibly a port admiral, in the West Indies. Oral traditions, though of value, are unreliable in details.

Ultimately, on recourse to more exact records, the following were found to be the principal facts of his career:

Gerrit (or Garret) Fisher was born at or near Albany on the 24th October, 1742, a member of a once noted New York family of Dutch descent usually spelling their name "Visscher." His branch was intimately allied with some of the principal manorial gentry who, before the Revolution and long after it, ruled that Province. It was intermarried with the Van Rensselaers, Schuylers, Wendells and others, who always supported with spirit the plans and operations of the armies engaged in the wars with Canada. In 1757, towards the closing year of those wars, a brilliant young Commander-in-Chief appeared at Albany—Lord Howe, "the earlier Wolfe," who, as a matter of fact, was greatly admired by Wolfe himself. The hopes of the British army and of its friends were placed upon him, until his lamented death in the battle of Ticonderoga in 1757. His own corps, the Fifty-fifth, or Westmoreland Regiment of Foot, reflected the fame of its colonel, and fought tenaciously when he fell, suffering heavy losses. It had been formed, partly in Scotland, in 1755 for service in America. After Lord Howe's death it came in 1759 under the colonelcy of a highly esteemed soldier, "that singularly worthy and benevolent character" Sir Adolphus Oughton, under whom it was known as "Oughton's Regiment," after a custom of the period. He is mentioned in Wolfe's will. "Oughton's" served with Sir Jeffrey Amherst's army in the conquest of Montreal and consequent final reduction of Canada. Several commissions were at that time thrown open to the young New York gentry; and thus, on the 8th of September, 1761, Garret Fisher entered as ensign.

On the declaration of peace in 1763, the Fifty-fifth were to have been sent home, but the conspiracy of Pontiac in that year caused them to be detained a further two years. A partial picture of their life in Western New York is contained in the charming pages of Mrs. Grant of Laggan's "Memoirs of an American Lady," the authoress's father having been an officer of the corps. Just as they were at length on the point of departing for Britain, they were once more detained and the greater part of them sent to the fever-haunted marshes of Pensacola in Florida, to their hearty disappointment. Among the latter was Fisher. They seem to have been partly in Ireland and partly in the Island of St. Kitt's at the outbreak of the Revolution in 1775, and returning served in that war until 1783. But family tradition states that Fisher was excused because of his relationship to many of the patriots in military positions, for families were much divided. This does not seem likely.

On the 5th of September, 1764, he was commissioned lieutenant; on the 12th December, 1770, adjutant; on the 23rd January, 1773, captain; on the 26th of September, 1787, major. At that time the regiment included a number of his Loyalist relatives. Cornelius Cuyler—nephew of that staunch Loyalist, "the American Lady"—was Lieutenant-Colonel; a lieutenant was Cornelius Cuyler, junior; an ensign was "John Visscher."

In 1790, the Fifty-fifth was quartered at Edinburgh Castle, where Kay, the miniaturist and etcher of portraits, took a sketch of "Major Fisher," accompanying the print of which, in Kay's "Original Portraits," is a brief word saying that the regiment was popular there for the exemplary behaviour of its officers and men. (Kay's portraits were very crude.) While there, it filled out its complement by drafts from the 35th and was ultimately moved to Newcastle, whence in time it was shipped to the Continent for active service. In after days it was united with the 34th as "The Border Regiment," of which the 55th became, and remains, the second battalion. On the 25th April, 1792, Fisher was made Lieutenant-Colonel of the 60th or Royal Americans.

On the 17th February, 1794, Fisher became the Lieutenant-Colonel of the 9th Foot or East Norfolks. We now come to his connection with events in Guadaloupe.

A rare volume exists, by the Reverend Cooper Willyams, A.M., entitled "An Account of the Campaign in the West Indies in the Year 1794, under the Command of Their Excellencies Lieutenant-General Sir Charles Grey, K.B., and Vice-Admiral Sir John Jervis, K.B., Commanders-in-Chief in the West Indies, with the Reduction of the Islands of Martinique, St. Lucia, Guadaloupe, Mariagalante, Desiada, etc., and the events that followed those unparalleled successes, and caused the loss of Guadaloupe." The author was a member of the Expedition as Chaplain of H.M.S. *Boyne*, the flagship of Admiral Jervis. The book, a wide quarto of over 200 pages, is handsomely printed and illustrated by elaborate West Indian views in mezzotint after drawings by the author. In some of these pictures the *Boyne* can be distinguished, and perhaps Colonel Fisher and General Grey. The copy belonging to the present writer was that of the author himself, containing notes, corrections, hand-coloured sketches, and extra blank pages.

"In the latter end of 1793," writes Willyams, "His Majesty, having determined to send a formidable armament to the West Indies . . . Lieutenant-General Sir Charles Grey, Knight of the Bath, was promoted to the rank of General in America, and Commander-in-Chief in the West Indies. Several officers of distinguished abilities were also appointed to act under him.'' One of these officers was Lieutenant-Colonel Fisher, Secretary to the Commander-in-Chief. The Commander's staff consisted of Major-General Thomas Dundas, Lieutenant-Colonel Symes, Q.M.G., Major Henry Grey, Deputy Q.M.G., Lieutenant-Colonel Fisher, Major Lyon, A.G., and four Aides-de-Camp. The Fleet consisted of 25 men-of-war, with between 6,000 and 7,000 picked troops. One of the vessels was named the *Quebec* and one of the military leaders was H.R.H. Prince Edward "on his arrival from Canada." Colonel Elias Durnford of the Engineers and Lieutenant Charles Walker Durnford are also names familiar to Canadians. Arriving at Barbadoes early in January they found signs of an epidemic of yellow fever. They first attacked the Island of Martinique. After very strenuous fighting from February 5th to March 22nd, Martinique was subdued and St. Lucia followed in like manner. In the capture of St. Lucia, Major Visscher, a relative of Colonel Fisher, was mentioned for spiking the enemy guns. These Islands were then considered most important conquests; the army received the thanks of Parliament, and the captured colours were placed in St. Paul's Cathedral with appropriate ceremony. On the 17th February Fisher was made Lieutenant-Colonel of the 9th regiment. Guadaloupe was next attacked and surrendered on the 22nd of April. Many were the gallant deeds recorded by the good Cooper Willyams, but the work of Colonel Fisher is at first concealed behind the active and successful planning of his superior, the Commander-in-Chief. And, doubtless, as Secretary he had a principal hand in the drafting of the Answers to the Articles of Capitulation of Fort Bourbon and other places. At length, however, events in Guadaloupe necessitated his active personal intervention. A very small garrison had had to be left on the Island. Yellow fever broke out and caused immense losses, including General Dundas, the deaths from this cause being thrice those from war. A large expedition from France was organized by the Revolutionary Government there to take advantage of the situation, and it was suddenly concentrated against the British in Guadaloupe, where it landed at Grande Terre. Sir Charles Grey immediately returned to the Island. A General Order dated *Boyne*, off Pointe a Pître, Guadaloupe, June 15, 1794, orders "the Grenadier companies of the 6th, 9th, 15th, 21st, 56th, 58th, 60th, 4th battalion of the 64th, 65th, and three companies from the Irish Regiments, to be formed into a battalion under the Command of Lieutenant-Colonel Fisher of the 60th regiment. . . ." On June 24th, by another General Order, "the two divisions of marines are to do duty with the battalion of grenadiers under the command of Lieutenant-Colonel Fisher." Several bitterly disputed actions took place in the difficult tropical mountains and swamps. The French royalists in general found common cause with the British. The Revolutionists armed and freed all the negroes. "On the 27th June the batteries at Grozier having opened as usual on Fort Fleur d'Epée, a detachment of our troops, under Brigadier-General Fisher, marched forward to attack a piquet of the enemy posted at Morne Mascot, from whence they drove them after a sharp contest, and established themselves as our advanced post, within musket shot of the fort." On the 29th the Revolutionists made an attack in strong force on Morne Mascot, "mounting the side of Mascot heights with colours flying and singing the national songs, covered by a heavy fire of round and grape shot from Fleur d'Epée, which prevented our grenadiers from shewing themselves till the enemy were close to them; on which General Fisher made them prostrate themselves on the ground and wait the approach of the enemy in that posture. The instant the republicans came within a few yards of them they started up, and an obstinate engagement commenced, which terminated at length by the grenadiers advancing to the charge, on which the enemy fled and were pursued down the hill with great slaughter. Our loss amounted to thirty killed and wounded. . . . Brigadier-General Fisher was hit three times by grape shot, which caused contusions only, and his horse was killed under him. . . . The day following the enemy again made an attempt, in equal force, against our post on Mascot, and was again repulsed with great loss. The rainy season being already set in, and the hurricane months now approaching, determined the Commander-in-Chief to make an effort to finish the campaign at once. From his success in the last two engagements, and the excellent manner in which he had planned the attack, it would no doubt have succeeded had his orders been punctually obeyed. The plan he had laid down was for a large body of troops under General Symes to march during the night and make themselves master of Morne Government, and the other commanding heights round the town of Point à Pitre, whilst himself at the head of the rest of his army was in readiness on the heights of Mascot to storm Fort Fleur d'Epée on receiving a signal from General Symes; but from some unfortunate misapprehension the whole of General Grey's well-conceived plan was rendered abortive, and the almost total destruction of our forces ensued. Brigadier-General Symes, having under his command the first battalion of grenadiers, commanded by Brigadier-General Fisher, and the first and second light infantry commanded by Colonel Gomm, with a detachment of seamen from the *Boyne* and *Veteran*, marched from the heights of Mascot about nine o'clock at night on the 1st of July." Then followed a long fatiguing march in the darkness through deep ravines, when they finally found themselves caught in a heavy enfilading fire of enemy batteries, "the most severe the oldest soldier ever witnessed." They fought desperately, but "the whole became a scene of confusion impossible to describe. Instead of any of the heights being attempted the greater part of the troops and seamen got into the town, where they were mowed down with grape-shot and musketry from the windows of the houses." General Symes was by this time badly wounded, and his horse killed under him; many officers were killed and desperately wounded. He had failed to carry out the plan of General Grey and had not revealed his own plans to any other officer. "At length General Fisher (the second in command, who, as well as every other officer on this service, was ignorant of General Symes's plans), sounded a retreat, and the miserable remains of this gallant party marched off, the enemy harassing them in their retreat." Thus the army was saved from utter destruction by Fisher's ability and presence of mind. Sir Charles Grey and his main army were now called to Martinique. In consequence of these misfortunes, followed by a terrible scourge of yellow fever, and the arming of all the slaves by the Revolutionists, as above stated, the small garrison left in Guadaloupe were in the end reduced and worn out. On the 9th of December, General Prescott consequently skilfully evacuated the Island by night. The unfortunate French royalists were inhumanly massacred by fiendish methods similar to those of the present Russian Bolsheviks. Sir Charles Grey and his suite had embarked once more with Sir John Jervis on the *Boyne;* and thus, with his staff, General Fisher reached England again on the 21st of January, 1795. Generals Dundas and Symes having been killed, General Fisher was the principal officer remaining of those who had set out from England with the Commander-in-Chief. The deeds of Fisher are stated in succinct form in Johns' "Military and Naval Heroes of Great Britain."

Among the numerous picked regiments included in this great Expedition were several with whom he had had, or was to have, the closest associations. The 55th (Westmorelands), the 60th (Royal Americans), the 9th (East Norfolks), the 17th, were all represented. He was loved and admired by all. So that it was not strange that he was in turn the Colonel of each. On the 17th of February, 1794, we have seen that he was commissioned Lieutenant-Colonel of the 9th in Martinique. On the 3rd May, 1796, he was appointed its Colonel. On the 23rd August, 1799, he was Colonel Commandant. On the 10th August, 1800, Brigadier —— serving on the Expedition to Cadiz under General Sir James Pulteney; on the 1st January, 1801, he became Major-General; was retired on "English half pay" in 1802. In 1807 he was Colonel Commandant of the 17th, which had been at Albany about 1760 with the 55th, and on the 25th of April, 1808, he was named Lieutenant-General, shortly before his death, which took place in that year at the age of 66.

He appears to have died at his town house on Manchester Square, London, which was also his address in 1795, and was probably built or acquired by him not long before. It seems to have been a house which Lord Palmerston intended to take soon after Fisher's death, and is described as "a very good one." He owned valuable property in Ireland, and had married there, probably about 1795, the Lady Sarah Trevor, of an old family closely related to the Marquis of Downshire and the Duke of Wellington. On some of his silver, hall-marked 1799, his coat-of-arms shows three alternate coronets and fishes naiant on a vert shield; quartered with the arms of the Trevors, a lion rampant on ermine and erminois. Lady Sarah was probably a relative of a fellow-officer of Fisher's in the 55th regiment in 1777—James Taylor Trevor, both being on the roll as captains in that year. After the General's death a considerable part of his estate consisted of money in the Bank of Dublin (£42,000), doubtless the proceeds of sale of his Irish possessions. His English estate was probated at the further sum of £90,000. His wife predeceased him, and as they had no children, he sent to his nephew—Nanning John Visscher of Greenbush, Albany, who had married Catherine Glen Van Rensselaer, daughter of the brave and chivalrous General Solomon Van Rensselaer, of the Battle of Queenston Heights—and offered to make him his heir; but as Nanning preferred his Albany surroundings the General made no will, but died intestate. Nanning was a Major in the American army and son of the General's brother, Colonel John Visscher, who had served during the Revolution and was beside Montgomery when he fell at Quebec. A cousin was the distinguished Brigadier-General Frederick Visscher of the Revolution.

Tradition states that word of General Garret Fisher's death came to his heirs in America accidentally. On the 19th of June, 1811, all the heirs signed an agreement empowering Major Nanning Visscher to go to England and represent them. He arrived in August and took out Letters of Administration there, and on the 12th of October took out letters in Ireland also. It appears from certain legal papers that he collected and converted most of the assets into American stocks and British goods within a year after he arrived in England. He remitted the stock to Barent Bleecker in Albany and the goods to Peter Remsen in New York, who sold the goods for him. The proceeds of the goods amounted to $400,000; of the stocks $123,000, making a total of $523,000, which was at that time considered an immense sum even in circles familiar with the wealth of the Van Rensselaers and Schuylers. Tradition states that the entire estate, as converted, was sent to America in a ship chartered for the purpose after the outbreak of the war of 1812, and that an order was issued by both the British and the American Governments instructing their war vessels not to molest this ship bearing the estate of the British General to his heirs in the United States. Doubtless considerable profit was made by the device of turning the British moneys into goods. In the family all these events naturally created much pleasurable excitement and were regarded as a kind of romance.

I am sorry that my further information is very defective. I know nothing about the General's life either in Ireland or London, about the place or nature of his Irish estates (although, I presume, they were in Downshire), the story of his wife and marriage, his army career, beyond the meagre particulars given above—not even his exact appearance, as I have never seen any picture better than the rude sketch by Kay; but I have reason to think he was a tall, dark, handsome man, of perfect constitution. I have a hope that others may yet add some of these particulars from army records, and from letters in the hands of the descendants of his English and Irish military friends, by whom he was evidently valued and esteemed, while other particulars may doubtless be gathered in the United States. What I have tried to do is to rescue from oblivion the memory of a hero of the Empire, and the Loyalist of the highest military rank.

Montreal, December 23rd, 1921.

The Westmount "Stone-lined Grave" Race
(An Archaeological Note)

By W. D. LIGHTHALL, LL.D., F.R.S.C.

(Read May Meeting, 1922)

A paper by the writer, entitled "Hochelagans and Mohawks," in the Transactions of the Royal Society of Canada for 1899, contains a cut of an Indian grave then recently opened, with twelve others, on the south-eastern slope of Mount Royal at Westmount Upper Level, Montreal. The remark accompanying the cut was that the skeletons were "buried in the *Mohawk* fashion." In 1898 I had published in pamphlet form a more detailed, though hasty, account of my discovery of this group under the title, "A New Hochelagan Burying-ground." The notion that they were Hochelagan or Mohawk—the two terms being in reality about identical in this connection—was drawn from the existence, about a mile to the eastward, of the site of the Town of Hochelaga visited by Jacques Cartier in 1535 and destroyed by Algonkins and Hurons probably somewhere about 1560. Later reflection tended to throw doubt on the connection of the skeletons with the Hochelagan race. More especially it became clear that the method of burial—the bodies being each covered with two or three pairs of rough slabs of limestone meeting over the body in A shape—was different from any Mohawk or other Huron-Iroquois form as far as I could find. I have come to the conclusion that the burying-ground is probably that of an Algonkin people, and, moreover, one unlike the known Algonkin tribes of the St. Lawrence and Ottawa Valleys, for these buried their dead without stone-lined graves, but oftenest covered by logs or small slab cabins. The Westmount method of sepulture resembles that of certain early Algonkin tribes of Missouri, Alabama, Kentucky, Tennessee and South-western New York. A valuable work was published in 1920 by the Smithsonian Institution Bureau of Ethnology, entitled "Native Cemeteries and Forms of Burial East of the Mississippi," the author being David I. Bushnell, jr., Its illustrations show several stone-lined graves in the States mentioned, some of the forms of stone-lining approaching the Westmount form. Mr. Bushnell remarks at page 44:

"Stone-lined graves—that is, small excavations which were lined *or partly lined* with natural slabs of stone—have been encountered in great numbers in various parts of the Mississippi Valley. They are discovered scattered and separate; in other instances vast numbers are grouped together, thus forming extensive cemeteries. . . . As to the form of the graves, they are rude fabrics, composed of rough flat stones." Mr. Bushnell quotes descriptions of many varieties. "No other form of burial is more widely dispersed in eastern United States . . . and stone-lined graves have been encountered up the Valley of the Ohio into Pennsylvania, western Maryland, and Virginia, and farther south they have been traced along the Tennessee from its mouth to the mountains, and a few scattered examples have been discovered in Northern Georgia Naturally the kind of stone with which they were lined differed in widely separated localities."

It is remarkable how widespread were customs of stone-lining throughout the prehistoric world. In Thomas Wright's "The Celt, the Roman, and the Saxon," London, 1885, which describes many kinds of prehistoric and early graves, certain stone-lined ones are pictured which resemble those of Westmount and the Southern Algonkins. Sometimes, in the later forms, Roman roof tiles were used to replace stones; and it is curious to note that the Southern Algonkins used pieces of broken pottery in the same way. And in South Africa, the method of burial of the prehistoric race called "The Cliff Dwellers of T'zitzikama," who inhabited caves and rock shelters along the greater portion of the sea-coast of South Africa,—having displaced the bands of manlike Chacma baboons from these shelters,—was similar in principle. It is thus described by the discoverer, Mr. F. W. Fitzsimons, F.Z.S., Curator of the Port Elizabeth Museum, in the *Illustrated London News* of December, 1921:

"When a cliff dweller died, a shallow hole was scraped in the debris. . . . The body was doubled up in as small a space as possible, with the knees drawn to the chest. It was then laid in the hole, on its side; a flat slab of stone was placed on the head and another on the body. Sometimes there was a third on the pelvis. . . . The deeper we dug, the more fragile were the remains, and eventually, at depths of from ten to twenty feet, we discovered the burial stones only, the bones having long since returned to dust."

One of the reflections from this extreme dispersion of the custom is, of course, the amazing antiquity and persistence of primitive customs. Another is the special enquiry concerning the relationship and advent of this Westmount race. It should be noted that: the site was solely one of burial; it contained skeletons of women, and a lame man, showing they were not a mere war camp; they were in good preservation in a dry soil on a slope; it was on an excellent hillside site for a village, sheltered and with a wonderful outlook and close to good springs; no objects were found except a single bead of prehistoric wampum and the flat grave stones and perhaps some smaller scoop-stones; more particularly, no traces of Hochelagan pottery or other Hochelagan objects were discovered. The village, if any existed, was apparently of a peaceful, very primitive people, living alone, preceding the advent of the Hochelagans (whom I estimate to have arrived about 1400), and racially connected more or less nearly with the Southern Algonkins. The pre-European archaeology of Canada is, unfortunately, an absolutely neglected field. Probably this note may serve as an insignificant contribution.

Montreal, March 6th, 1922.

[Since the above was written I have read with eager concurrence the new article on "Anthropology" by Dr. G. Elliot Smith of London University, in the extra volumes of the *Encyclopaedia Britannica*, in which he outlines the current revolution of opinion regarding the alleged autochthonous origins of New World civilizations and customs. The custom of stone-lining graves is another instance of the origin of American Indian customs in the Old World. The new order of ideas seems perhaps destined to solve the mystery of the Central American civilizations and offers a line of decipherment of their hieroglyphs by comparing them with early Japanese, Chinese and South Asiatic, and ultimately Egyptian, glyphs.—W. D. L.]

University Development in Canada

By WALTER C. MURRAY, M.A., LL.D., F.R.S.C.

(Read May Meeting, 1922)

Introduction

Twenty-two universities, including Trinity and Victoria, which are federated with Toronto, are reported in the last Year Book of Canada.[1] Eleven are east of the Ottawa, and four west of the Lakes. All the Western universities are controlled and supported by the State; only one of the Eastern is a State university. Eight others owe their origin and support to the Churches. Two, and two alone, are independent of both Church and State. In Ontario, the middle ground, all owe their origin to the Churches; two are still dependent upon them; two are uncontrolled by Church or State, but hopeful of sympathy and support from both; while Toronto combines State control and support with the co-operation of the Churches.

As one passes from East to West one may see in existing institutions, survivals of the different stages of University Development in Canada, from the opening of the Seminary in Quebec in 1663 to the present time. It is a story of the struggle between Church and State for control; a struggle forced upon the State by sectarian strife.

In the beginning, the Churches established the Colleges, the State granting aid. Then when one Church claimed exclusive privileges, sectarian strife led to a division of State aid. The bitterness of the strife, and the wastefulness of the system of denominational grants, forced the State either to assume control of one college and deny aid to others controlled by the churches or to repudiate all responsibility for university education. Before the State reached this decision attempts were made to unite the competing colleges under State leadership and with State support.

In Laval, in Quebec, survives the first experiment in higher education—Church leadership with State aid. In the division of grants among the four universities of Quebec persists the first compromise to preserve peace. In New Brunswick there is State control with meagre support of one college, but without the co-operation of the churches. In Toronto and Manitoba there is denominational co-operation with support and control by the State. In Nova Scotia

[1]Year Book of Canada, 1920, p. 156.

in the east, and British Columbia in the west, are the extremes of State paralysis and State monopoly. In McGill and Dalhousie private enterprise has achieved, independently of both Church and State, results worthy of the best British tradition. In Queen's the national impulse, quickened by Principal Grant, burst the bonds of Church control and Queen's sought, like Western, in the enthusiasm of its community and graduates, the strength and support required to meet the needs of recent University development.

The Five Periods

The story of the development of the universities of Canada embraces at least five distinct periods. Each period is marked by movements with far-reaching political effects. These movements are reflected in the fortunes of the colleges no less than in the political development of the country.

I. *French.*—The first period is French, covering nearly a century and a quarter and ending with the American Revolution. In it the flickering lamp of learning in Quebec made darkness visible.

II.—*The King's Colleges.*—The second period begins with the inrush of the Loyalists, who brought clear-cut ideas of government, religion, education and the administration of justice. From 1785 their ideas prevailed and established British institutions in Canada. They set up the King's Colleges for the preservation of the British connection and the Established Church of England.

III.—*The Sectarian Colleges.*—The third, from the twenties to the sixties, was a period of strife—strife against the rule of the few in the State and against exclusiveness in religion and education.

The challenge to the authority of the Established Church was followed by the founding of sectarian colleges demanding equal privileges from the State. In the political sphere open rebellion against the Family Compact led to the establishment of Responsible Government and the extension of democratic control to the colleges dependent upon the State.

IV. *College Union.*—The fourth period, that of Confederation, witnessed a reaction against the strife and waste of the previous period. The provinces sought to compose their differences by entering into a larger union. This was followed by attempts at union between the colleges in Nova Scotia, in Ontario and in Manitoba. For fully thirty years the energies of the people were directed to the establishment and strengthening of political, economic, religious and educational unions.

V. *State Universities.*—The fifth, the period of national expansion, saw the national consciousness developing a sense of pride and responsibility in the opening of the West and in Dominion participation in Imperial affairs. The universities felt the new impulse. The Toronto Commission of 1905[2] declared the new faith of the nation in universities, and in recasting the constitution of their own university framed the model of the new universities established by the Western Provinces in 1906, 1907 and 1908.

Thus the universities, no less than the political institutions of the nation, reflect the spirit of the people. The intense devotion of the Loyalists to King and Church reappears in the King's Colleges. The revolt of the radicals prompted the establishment of Sectarian Colleges. Responsible government led to democratic control of the colleges supported by the State. Political Union of the Provinces was followed by unions among the colleges and among the churches. The growing national consciousness found expression no less in the reorganization of Toronto and the establishment of new State universities than in the opening of the new land, the expansion of trade, and the larger participation in the affairs of the Empire.

When the Great War descended upon us, none responded with greater alacrity and determination than the youth in the universities. Through them the nation and the universities were knit together with ties which will hold while the memories of the race endure.

The Five Types

The Canadians are migrants. As they moved overseas or from east to west they carried with them customs, ideas and institutions which they transplanted in the new soil. The School System of Ontario reappeared on the Prairies. The political institutions, the churches, the schools and colleges of the old land were copied in the new, with sometimes too little regard for novel and differing conditions.

I. *French.*—It was natural that Quebec should copy France. To this day the universities of Laval and Montreal reflect the French conception of the university as a collection of professional schools and as an agency for the examination of candidates, and the granting of degrees which carry certain rights and privileges.

In the Classical Colleges scattered over that province, students are trained and prepared in the languages, science and philosophy for the examinations set by the university. From these colleges the

[2]Report of University of Toronto Commission, pp. XX, LIII, LIX.

successful bachelors may pass into one of the professional schools of the university.[3]

II. *Oxford.*—The second type appeared in the King's Colleges. It came from Oxford. Its aim was "to give a gentleman that broader and deeper culture with which custom demands he should be equipped." [4] This was given through traditional studies in the classics, mathematics and philosophy. "Teachers and students lived together in the college in a sort of monastical society." These colleges insisted upon residence with strict supervision and naturally made religion an essential element in this training.

III. *Scottish.*—The third type, the Scottish, emerged during the period of sectarian strife. It was more democratic and emphasized learning rather than training. "It was open to all occupations and sects of religion."[5] It perpetuated the Bologna type of university where scholars gathered from far and near to hear the great doctors expound the principles of law and comment on the codes of the Romans. Where and how the student lived and what he believed were matters of little or no concern to his teachers.

IV. *London.*—The desire to unite the colleges found a fourth type in London, where an attempt had been made to provide for students who were excluded from Oxford or Cambridge by religious beliefs, or the lack of them. These students underwent severe examination tests. The few who were successful received degrees whose standing was unquestioned. From the University of France, as recast by Napoleon, came the idea of the examining and degree conferring University of London. It was a matter of indifference to the university where the teaching was done, or when, how, or by whom candidates were prepared for the examination. This type of university permitted colleges the most diverse in religious belief and in government, the most distant in situation, to conduct their teaching as they wished, and yet to join in submitting their students to a common test and to receive the same degrees.

V. *State University.*—The fifth type, dominating the period of national expansion, is the State University. It does not ignore the necessity of training, or the desirability of residence, yet it is open to all sects and occupations, and it makes the advancement of learning and the application of science to the service of man a fundamental aim. Moreover, since it receives its support from the people it must be subject to their control and carry to them what they need but can-

[3]Universities Handbook, Universities Bureau.

[4]Paulsen: German Universities, p. 1.

[5]Lord Dalhousie's Letter to Earl Bathurst, Dec. 14, 1817, Hind, King's College, p. 50.

not receive within its walls. Such a university, instituted, supported and controlled by the State, is in duty bound to the State to train its young men and women for good and useful citizenship, to engage in research and the application of science to the needs of man, and to extend the sphere of its usefulness far beyond the narrow limits of its campus. Teaching, Research, and Extension are the three forms of its service. Its purpose is not to combat the religious or other interests of the people, but to co-operate with them. As it cares for the different phases of public well-being it increases in usefulness and merits the support which the people generously give.

The French Universities

Of the French universities of Quebec I may speak briefly. They have developed apart from the current of university life elsewhere in Canada. The Seminary of Quebec, which became Laval in 1853, was founded, like the King's Colleges, on the assumption that all education, collegiate as well as primary, must be based on religion.

In Quebec the authority of the Roman Catholic Church to determine the character of that religious education has not been challenged like that of the Church of England in the other provinces. In consequence, the State has never been forced to assume control of university education.

In Laval to-day may be seen a survival of that relation between Church and State, with regard to university education, which was common in the older provinces in the beginning.

The Montreal branch of Laval, established in 1878, was incorporated in 1920 under the name of the University of Montreal, and while still in sympathy with the Church and independent of State control, has become more secular in its management. Its academic and its business affairs are managed by separate boards; while its appointments are made by the faculties.

The King's Colleges

The first impulse to university education among the English in Canada came from the Loyalists. That impulse gave direction and character as well as impetus to the movement.

In 1783, the year in which Britain acknowledged the independence of the United States, five clergymen in New York prepared a memorial urging the establishment of a school or college in Nova Scotia. This memorial[6] was forwarded to Lord North, Prime Minister of Great

[6]N.S. Hist. Soc. Coll., vol. 6, p. 125.

Britain, by General Sir Guy Carleton, afterwards Governor-General of Canada. The first[7] to sign the memorial was the Rev. Charles Inglis, Rector of Trinity, N.Y., who afterwards became Bishop of Nova Scotia. Four years later Bishop Inglis had the pleasure of establishing first a school, then an academy, and in 1789 a college at Windsor, Nova Scotia.

In 1785 a similar memorial[8] was presented by Dr. Paine and others to Governor Thomas Carleton (brother of Sir Guy), of New Brunswick, asking for a college. This led to the establishment of the College of New Brunswick in 1800.

In 1789 Richard Cartwright, a Loyalist from New York, addressed a memorial to the Governor-General of Canada, Lord Dorchester, formerly Sir Guy Carleton, suggesting an appropriation for a "decent seminary of education" [9] at Kingston. The division of the Province of Quebec in 1791 prevented action. Governor Simcoe of Upper Canada, in 1795, suggested to the Bishop of Quebec that he promote the establishment of a university in Upper Canada. The following year he urged the Home Government to set aside lands for this purpose.

His departure indefinitely postponed the project. Hon. R. Cartwright and his friends, Hamilton and Stuart, sought in Scotland a tutor for their children. It is said[10] that Thomas Chalmers could not accept the invitation but recommended John Strachan of Aberdeen. The arrival of John Strachan led ultimately to the establishment of McGill College, through the gift of James McGill, also to the grant of a Royal Charter to King's College, Toronto, in 1827, its opening in 1842 and to the founding of Trinity in 1851.

Bishop Mountain of Quebec, stimulated by the action of the Loyalists, approached the Legislature of Lower Canada and secured the passing of the Act, establishing the Royal Institution for the Advancement of Learning in 1801.[11]

The natural anxiety of parents to give their children a good education was re-enforced in the case of the Loyalists by religious and political motives. They appealed to the British Government for aid, for they themselves had lost everything; they appealed for immediate aid, since their children's education had been rudely interrupted by their departure from the States. They abhorred the idea of exposing their children to the republican ideas of the schools which they had left.

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[7]Hind: King's College, p. 8.
[8]Trans. Roy. Soc., 1918, vol. XII, p. 96.
[9]Universities of Canada, p. 7.
[10]Bethune: Memoir of Bishop Strachan, p. 7.
[11]Macmillan: McGill and its Story, p. 19.

In urging upon Lord North a "plan for religious and literary institution in Nova Scotia," [12] the clergymen of the Church of England were prompted by political as well as religious motives. They pointed out that "The influence of religion on political institutions as well as on the moral conduct of men, has been universally acknowledged by the best and worst of men. Experience has also shown the conformity and eligibility of certain modes of worship to particular forms of government, and that of the Episcopal (abstracted from its antiquity and apostolic sanction) has been thought peculiarly adapted to the British Constitution."

"Besides the ample proof which the history of the nation has afforded of this circumstance, it has been particularly conspicuous in the origin and progress of the convulsions of the country. There was not only a considerable *majority* of loyal subjects in almost every Episcopal congregation from Carolina to Nova Scotia (a few influences perhaps in Virginia alone excepted), but some were found which scarcely produced one disaffected form of character, whilst the clergy were permitted to exercise their functions."[12]

Doubtless the Rev. Charles Inglis and his fellow memorialists had in mind what King's College, New York, founded in 1754, and the College of William and Mary of Virginia, founded in 1660 (the second oldest college in the United States), had accomplished for the Church of England and the British connection. In each, the Church of England had a privileged position. Its liturgy was used; some of the officials were members of that Church, and in Virginia subscription to the Articles was required. Each had been a centre of British influence and because of this had become so obnoxious to the revolutionaries that King's College was transformed into Columbia, and William and Mary supplanted by the University of Virginia, established by Thomas Jefferson, an alumnus of William and Mary.

To accentuate the British connection, the Canadian colleges notwithstanding the provincial statutes under which provision had been made for them, applied for Royal Charters. These charters were granted to King's College, Windsor,[13] in 1802; to McGill College in 1821; to King's College, Toronto,[14] in 1827. In 1828 the College of New Brunswick became King's College, Fredericton, under Royal Charter.[15]

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[12]N.S. Hist. Soc. Coll., vol. 6, p. 125.

[13]Hind: King's College, p. 26.

[14]Bethune, p. 109.

[15]Hannay: Wilmot and Tilley, p. 50. The Fredericton Charter a copy of Toronto's.

These charters[16] gave to each college a governing board composed mainly of crown officials—the Lieutenant-Governor, Chief Justice, Attorney-General, Speaker of the Assembly, the Bishop and others also, chiefly officials. They gave the Church of England a privileged position[17] with regard to the composition of the Board, the President, the professors in the Council, the teaching of Divinity, and in some cases the matriculation and graduation of students.

These charters proved a serious embarrassment to reform. They enabled the college authorities to resist the attempts of the Legislatures to bring them into conformity with the wishes of the people. Even the British Secretary of State was unable to enforce his demand in the thirties for the surrender of the Royal Charters of the King's Colleges at Windsor, Fredericton and Toronto.[18] All he could do was to withdraw the Imperial Grants and to give the Provincial Legislatures permission to do what they could to delay or regulate the operation of the colleges.

Under these charters the colleges became practically private institutions, although receiving State aid. A similar issue had arisen when the Legislature of Connecticut tried to control Yale College in 1763.[19] In the famous Dartmouth College case, in which Daniel Webster appeared, the Supreme Court of the United States gave the decision in favour of the college in 1819. The power of the Legislature of New Brunswick to amend a Royal Charter was tested in the courts and confirmed, when Dr. Jacob retired in 1859.[20]

It may be remarked in passing that the decision in the Dartmouth College case forced the State Legislatures to adopt another form of government than that of the close corporation for the colleges and universities to which they were to give aid.

The King's Colleges followed the Oxford model, though in the beginning I have no doubt King's College, New York, through Bishop Inglis, and the Loyalists from that State, suggested many things. It is interesting to note the great similarity between College development in the United States and in Canada—a similarity so great that it suggests direct influence from the days of the early King's Colleges to the present State universities. This, however, is unlikely, because the Loyalists were in no mood to look to the United States for models,

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[16]Hind, pp. 74-81.

[17]Hannay: Wilmot.

[18]Universities of Canada, p. 26; University of Toronto, 1827-1906, p. 17; Bethune, p. 33.

[19]Brown: Origin of American State Universities, p. 19.

[20]Universities of Canada, p. 33.

and the Reformers knew that United States authorship of their proposals would be damning. This similarity seems to be due rather to common British traditions working out in similar conditions, instruments for the expression of those ideals and the realization of those purposes which have been the constant pursuit of the British race.

King's College, New York, and the College of William and Mary in Virginia, reflected more fully than any other in the States the British tradition in government, curriculum, methods of instruction and mode of living. The first college proposed for Virginia was to bear the name of Academia Virginiensis et Oxoniensis.[21] The New York College turned with equally reverent eyes to royalist and ecclesiastical Oxford. To the Church of England, to the Classics, to the residential system and student government of Oxford, King's College, New York, accorded the honour of first place in its organization and practices.

The influence of Cambridge, with its traditions of Roundheads, Cromwell and Science, predominated in Harvard and revolutionary Massachusetts. It was not until sectarian strife gave rise to denominational colleges that the New England influence penetrated into Canada. Possibly the "New Light" movement, which swept over New England and was carried into Nova Scotia by Henry Alline, preparing the way for the Baptist Church in that province, was responsible for the opening of the door in Canada to the New England College teacher and tradition.

Sectarian Strife

In the "political" boards and the exclusive privileges granted to the Church of England lay the seeds of the troubles that afflicted the King's Colleges for more than a generation.

Doubtless the method of selecting the Governors, from officials of the Crown, secured able men, well-educated and experienced in business. In a new country it was perhaps the only method of securing properly qualified men. (*Cf.* Harvard's first Board of Overseers.) It also secured, whether by intention or not, governors in sympathy with the Church of England.[22]

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[21]Thwing: History of Education in America, p. 51.

[22]In New Brunswick every member of the Governor's Council, until its abolition in 1833, was an adherent of the Church of England, with the solitary exception of William Pagan, a Presbyterian. L. A. Wilmot was the first Attorney-General, 1848, and the first Judge of the Supreme Court (1850) of the Province who was not of the Church of England. Hannay: Wilmot, p. 7.

Unfortunately the colleges, through their Governors, became involved in the bitter political struggles of the time, and their defence of the privileges of the Church became an object of attack by the Reformers. When the Governor and his Council resisted the aggressions of the Assembly, upon his prerogatives, the college sympathized with His Honour. When the Bishop was threatened with the loss of the Clergy Reserves, he naturally expected protection from the Governor and his Council. The Governor and the Bishop became identified with the college and drew upon it not a little of the fire intended for them.

Again and again a little yielding by the Governor or the Bishop might have permitted the college to escape. Ecclesiastical bigotry called Dalhousie into being and twice prevented its union with King's, and the beginning of a University of Nova Scotia. The stubbornness of Dr. Bethune, pupil of Dr. Strachan, delayed the development of McGill for more than a decade. The ability, intolerance and energy of Bishop Strachan exposed King's College, Toronto, to a storm of sectarian abuse that led to the establishment of denominational colleges and delayed the establishment of a national university for sixty years—until 1887. Nevertheless, his vision, energy and enthusiasm for learning were responsible for the beginning of both McGill and Toronto.

The colleges suffered more from the claims of the Church of England for exclusive privileges than they did from the political character of their boards. The Church claimed a controlling voice in the governing boards, requiring the President to be a member of that Church, and the professors and students to subscribe to the XXXIX Articles. The use of the Liturgy in college services was also prescribed.

It is curious to note that subscription to the XXXIX Articles was also required by the old Virginian College of William and Mary, which had been fashioned in the likeness of Edinburgh. Thwing declares that the purpose of the subscription to this college was "rather to promote loyalty to the home government" than orthodoxy.[23]

The disclosed political purpose of the memorial to Lord North, on behalf of a college in Nova Scotia, suggests a similar belief with regard to the King's Colleges. Judge Croke, in his protest against the abrogation of the objectionable statutes of King's College, Nova Scotia, said: "I do hereby express my disapprobation of the repeal of the said two statutes as injurious to the interests of true religion in

[23] Thwing, p. 60.

general, of the Church of England in particular, and from the connection which exists between them to His Majesty's Government and the British Constitution." [24]

The founders of King's College in New York declared that "There was no intention to impose on the scholars the peculiar tenets of any particular sect of Christians." [25] It was otherwise with the early governors of King's College, Nova Scotia. Judge Croke, a graduate of Oxford, an able and bigoted "Tory of the Old School," prevailed upon the Board to follow Oxford and pass these objectionable statutes.

"No member of the university shall frequent the Romish mass or the meeting-houses of the Presbyterians, Baptists or Methodists, or the conventicles or places of worship of any dissenters from the Church of England, or whose divine services shall not be performed according to the Liturgy of the Church of England or shall be present at any rebellious or seditious meetings." "No degree shall be conferred till the candidate shall have subscribed to the Thirty-Nine Articles and the Three Articles of the Thirty-Ninth Canon of the Synod held in London in 1603." [26] This was passed in 1802 in spite of the protests of Bishop Inglis, who knew what had happened in New York and New England.

It is not difficult to understand why such extreme views should find favour with the Loyalists who had suffered so much for their King and Church; nor is it difficult to imagine the resentment of three-fourths of the people who were excluded from a college for which they were taxed.

A long and bitter fight led to a modification of the statutes of the Windsor College. At first, subscription to the XXXIX Articles was postponed until graduation, then abolished. The students were free to attend such religious exercises as their parents wished, but were required to be instructed in religion and were strictly supervised while in college. Tests for professors were withdrawn, except for Professors of Divinity, but until the end the President was required to be a Clergyman in Holy Orders and the control of the Governing Board was to remain in the hands of members of the Church of England.

Bishop Strachan was not so thoroughgoing as Judge Croke. Subscription to the XXXIX Articles was not required of the students or graduates of King's College, Toronto, but the Church of England

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[24] Hind, p. 45.

[25] Thwing, p. 116.

[26] Life of Thomas McCulloch, p. 39.

was given a dominating place in the Governing Board; the Bishop was Visitor, the Archdeacon, President, and the Professors constituting the Council were to be members of that Church,[27] and, worst of all, the large endowment of lands and the provincial and imperial grants were thus in the service of one Church.

The radicalism of Canada first spoke through Scotsmen—McCulloch and Mortimer in Nova Scotia,[28] Glennie in New Brunswick[29] and Gourlay in Upper Canada.[30] As in the United States, the Presbyterians bitterly resented the claims of the Church of England, for they too claimed the rights of establishment. McCulloch, though a member of a branch of the Presbyterian Church that had seceded from the Established Church of Scotland before the Disruption, had a good educational reason for his attack. Pictou Academy, which he had founded, was a suppliant for a grant. The Assembly favoured the grant; the Governor and Council resisted. Religion, as well as politics, entered into this struggle of thirty years, which culminated in the attainment of Responsible Government in 1848.

Lord Dalhousie, a Scotsman, the Governor of Nova Scotia, was the first to express in action his protest against the exclusiveness of King's College, Windsor. Over £11,000 had been collected as duties by the British when they held the port of Castine in Maine during the war of 1812. Lord Dalhousie decided to recommend that these funds be used for educational purposes. In his letter to Lord Bathurst, December 11, 1817, he says: "I formerly thought that it might be applied to the removal of King's College to a situation here more within our reach; but I am better informed now, and I find that if that College were in Halifax it is open to those only who live within its walls and observe strict College rules and terms. . . . It has occurred to me that the procuring of a College on the same plan and principle as that of Edinburgh, is an object more likely than any other I can think of to prove immediately beneficial to this young country. . . . These classes are open to all sects of religion."[31] His recommendation was adopted in 1818 and the building of Dalhousie College begun in 1820. The college had as Governors officials who were more interested in King's. It remained unopened for twenty years—until McCulloch was transferred from Pictou to it in 1838.

[27]University of Toronto, 1827-1906, p. 12.

[28]Life of Thomas McCulloch.

[29]Glennie, Hannay: Wilmot.

[30]Bethune: Strachan, c. 7; Wallace: Family Compact, c. 3; Kingsford, vol. LX, pp. 207-239.

[31]Hind, p. 50.

The opening of Dalhousie and the transfer of McCulloch to its Presidency, instead of quieting sectarian animosities, led to a greater outburst than ever.[32]

It seems that three professors were to be appointed—McCulloch to the Chair of Philosophy, MacKintosh to the Chair of Mathematics, and another to the Chair of Classics. Crawley, who had been a member of the Church of England, but had joined the Baptists, a man admittedly well qualified, had applied to the Governors for the appointment. Three Governors only were active—the Lieutenant-Governor, Colin Campbell, C. W. Wallace, son of a former treasurer, and S. G. W. Archibald, Speaker of the House of Assembly. Archibald and another promised support and Crawley and his friends felt assured of appointment a short time before the meeting of the Board. But in the interval it was represented to the Governor (a brave soldier, as the Indian Mutiny showed, but a poor statesman) that McCulloch was a Seceder and a well-known Reformer; that Crawley was also a Dissenter and that between them they would control the college to the detriment of established religion and the government of the province. Political considerations, reinforced by religious, prompted the Governor and Wallace to reject Crawley and appoint another. They gave as a reason that Dalhousie was by the founder intended to be like Edinburgh, and that in Edinburgh only members of the Established Church of Scotland were professors.

Disastrous effects soon became apparent. Acadia College was established by the Baptists and each sect felt in duty bound to do likewise. Nova Scotia to-day has within its borders eight or nine institutions with degree conferring powers, notwithstanding the disappearance of the Congregationalist and the two Presbyterian Colleges, and the Medical School, which Dalhousie has absorbed. Mt. Allison University, at Sackville, N.B., also renders service to Nova Scotia. This epidemic of Sectarianism has blighted university education for a century in a province with a capacity to emulate old Scotland.

It is well to remember the year of this misfortune—1838. The political passions of the time had burst forth in the Rebellion of 1837. In the religious and educational spheres, passions were running almost as high.

Ontario fared no better than Nova Scotia. The amendment of the Royal Charter of King's College in 1837 had come too late. Within a year or two of its opening in 1842, Victoria College was

[32]Dalhousie Gazette, vol. 35, pp. 137-140.

opened at Cobourg, Queen's and Regiopolis in Kingston and Knox in Toronto. For over forty years there was unceasing strife.

The attainment of Responsible Government in 1848 gave the people control of the college as well as of the government. In 1849 Robert Baldwin amended the Charter of King's College, removing all trace of ecclesiastical domination. At once the State college was assailed with the charge of "godlessness." Even the colleges, which had been attacking because of Anglican exclusiveness, now sympathized with Bishop Strachan, who had founded Trinity in protest,[33] and justified his action by branding the State's college as "godless." The Baldwin Act was amended to meet this criticism.

The strife between sects became a strife between sectarianism and non-sectarianism. Toronto, McGill and Dalhousie were reproached for their supposed "godlessness." Their sectarian rivals were branded as "narrow." It was claimed that where dogmatic instruction in Theology could not be given, there no development in Christian character could take place. Only the denominational college could surround the growing youth with those Christian influences so necessary to the growth of virtue. On the other hand, the "narrow" denominational college was supposed to be hostile to intellectual liberty, and to the untrammelled pursuit of truth by Science. This conflict and these suspicions persisted well into the next century, although Toronto recognized Religious Knowledge in its curriculum and McGill and Dalhousie welcomed Theological colleges to affiliation and places on the campus. In the western State universities affiliated theological colleges have accepted places on the university campus and an important part in university life.

A new spirit with greater faith in education and a greater desire to serve all was manifesting itself throughout the provinces. William Dawson, Superintendent of Education for Nova Scotia, was awakening the people. Egerton Ryerson was fighting for educational reform in Ontario. He and Dawson were appointed on a commission to advise the Government of New Brunswick what to do with their King's College, which had fallen short of public expectations. They recommended its transformation into a University of New Brunswick, to be controlled by the State and assisted to give greater service by exploring the resources of the province and making greater provisions for the sciences and modern languages in the College curriculum. This was done in 1859. In 1855 Dawson began the great task of revivifying and reconstructing McGill into one of the great Science Schools of the Empire. The new spirit of Science which

[33]Bethune: Memoir of Bishop Strachan.

he introduced into McGill had already received recognition in Toronto. Where New Chairs in Agriculture, Physics, Geology, Natural History, Engineering, History, English and Modern Languages, had been established and applications received from able and distinguished graduates of British universities.[34] Huxley and Tyndall were among the number.

The State aid which the King's Colleges received was always an object of attack. Naturally the denominations demanded a share of State aid for their colleges. In Nova Scotia, Pictou Academy received a grant in 1819 and thereafter, with varying success, applied each year for aid. In 1845 the principle of denominational grants was adopted by Nova Scotia,[35] and until 1881 the system was continued, though modified from time to time to escape undue sectarian pressure. In Ontario the denominational grants were discontinued in 1868.[36] They seem to have been begun in the forties. These grants led to the multiplication of recipients of grants—eight or nine in Nova Scotia and as many more in Ontario. The basis of the distribution varied from a fixed sum for each institution, without respect to work, needs or rank, to so much per capita for each denomination distributed as they wished; or to a *pro rata* amount determined by the number of students and character of work.

It is not surprising that disgust and intense dissatisfaction developed over these sops to sectarianism, which bred strife and embarrassed education by multiplying divisions and preventing the extinction of the unfit and useless.

College Union

Union was advocated as a panacea for the ills of the body politic. The Union of the Canadas in 1841, of the Provinces in 1867, was reflected in attempts to unite the colleges and so escape the bitterness, the waste and inefficiency of sectarian competition in educational and in religious matters. In Ontario the spirit of union was more effective than in Nova Scotia. Union of the Canadas, Confederation of the Provinces, were reflected in the National Unions of the Presbyterians in 1875, of the Methodists in 1884, and in the projected college unions of 1843, the unions in the Universities of Halifax and Winnipeg in 1876, and in the Toronto Federation of the Universities in 1887.

In Nova Scotia several attempts at union of the colleges were made, but with minor results. In all of these attempts Dalhousie

[34]University of Toronto, pp. 35, 107.

[35]Dalhousie Gazette, vol. 35, p. 171.

[36]Hodgins: Schools and Colleges of Ontario, vol. 3, p. 25.

University played a prominent, and with one exception a friendly, part. In the largest and most promising of all, the University of Halifax, Dalhousie reversed her usual *rôle* and played the part of destructive critic.

Union was first proposed between King's and Dalhousie in 1823, and union between these colleges has been seriously considered at least five times within the century. It would be wearisome to restate the proposals and to repeat the arguments for and against. Governor Kempt suggested union after the Dalhousie building had been erected, but before it was opened. Dalhousie had the building and the advantage of location, but needed a charter, staff and students. These King's had, but needed funds for buildings and a better location. Both needed more funds and the united support of the Province. Terms were drafted and submitted to the Board of King's. They failed to receive approval in the face of the opposition of Chief Justice Blowers, who declared that the removal of King's from Windsor and the abandonment of the Royal Charter involved a "breach of trust in which a present and acknowledged good was to be sacrificed for uncertain and future advantage."[37]

A second attempt, extending over seven years, met with no better success, though it originated with a despatch from Sir George Murray, Secretary of State in 1832. Two years later Lord Goderich followed with an announcement of the termination of the Imperial Grant. In 1833 Lord Stanley renewed the suggestion, and in 1835 Lord Glenelg asked for the surrender of the Royal Charter. The Bishop and the Legislative Council, which was then engaged in a bitter controversy over the grant to Pictou Academy, protested and invoked the veto of the Archbishop of Canterbury. They succeeded, and for well-nigh half a century the union of King's and Dalhousie ceased to be a living issue.

Fifty years later, in 1885, Confederation of King's with Dalhousie was again before the King's Board and again the Royal Charter and local feeling defeated the proposal to remove it from Windsor to Halifax.

A fourth attempt was made in 1901.[38] Meetings were held and negotiations advanced to the preparation of an Act for a Maritime University. In it King's and Dalhousie were to have an equal voice, though Dalhousie was to surrender its name charter and property, without reserve, to the new university, while King's retained its

[37]Hind, pp. 60-81.

[38]King's College, Windsor, College Federation, Pamphlet with Report to Diocesan Synods, June, 1902.

Royal Charter intact except with respect to the conferring of degrees. It also retained its trust funds and kept its ordinary funds separate, though permitting their revenue to go to the common chest. Yet again Windsor and the Royal Charter interposed their veto.

A fifth attempt was initiated by King's, twenty years later, when King's had almost reached the portals of extinction and Dalhousie had increased fivefold. Equally generous were Dalhousie's proposals and equally timid and hopeless were the decisions of King's. A retired situation, a Royal Charter and an ancient tradition are insecure supports for an impoverished college at a time when university education requires hundreds of thousands, where tens of thousands sufficed two decades before.

Within a year the question of College Union was reopened by the proposals of the Carnegie Foundation for the advancement of Teaching.

Dalhousie College was more fortunate in other ventures. The Arts department of Gorham College, established by the Congregationalists at Liverpool, N.S., was transferred to Dalhousie in 1856, "with a view to the furtherance of the establishment of a Provincial University." The transfer failed to bring the college to the standing of a university. One of the Congregational professors, Dr. Cornish, followed Principal Dawson to Montreal and served under him in the new McGill.

More fortunate was Dalhousie in 1863, when the two great political rivals, Joseph Howe and Charles Tupper, joined in blessing the project to reorganize Dalhousie with the co-operation of the two branches of the Presbyterian Churches and to establish a university non-sectarian in character and independent in government. With George Grant and Allan Pollok collecting funds, Chief Justice Young and Principal Ross guiding the policy, and a brilliant group of young professors, MacDonald, Johnson, Lawson, DeMille and Lyall, setting a new standard in teaching, the reorganized and united university soon sprang into esteem and was the recipient from George Munro of the first of the large benefactions made to the universities in Canada by private donors.

These unions in Nova Scotia took place before Confederation. A federal scheme of Union was proposed for the colleges in the Maritime Provinces in the seventies. It was a copy of the London University which, in the spirit of Napoleon's creation, restricted its activities to the examination of candidates and the conferring of degrees. Each denominational college was to be left free to teach as it wished, and was given representation on the Senate of the new university and from its teachers examiners might be chosen.

In 1876 the government granted the University of Halifax a charter,[39] and in the hope of being freed from the giving of denominational grants, gave it a modest grant. Acadia, Mt. Allison, King's, St. Francis Xavier and St. Mary's received the proposal with favour. A section of Dalhousie's staff and students were coldly critical of the "paper" university, predicted debased standards and "cheap" degrees. They claimed that more teaching was needed, not more examinations and cheaper degrees. In a sense they were right, but they had not the vision to see that this university might in time become a truly provincial institution, receiving provincial support, making teaching in the Arts and Sciences its chief business, and gathering within its fold professional schools of Law, Medicine, Dentistry, Engineering, Pharmacy, Education and Agriculture.

In Winnipeg the University of Manitoba, beginning in like manner in 1878, grew from a purely examining and degree conferring institution first into a teaching School of Science, then of Arts and Science, then a cluster of professional schools, until it emerged from all the limitations of the first compromise into a large and vigorous university. With surprising fidelity does Manitoba reproduce the more notable features of the University of Toronto, which, after fifty years of wandering in the wilderness, beset by foes without and mutiny within, weakened by privation, and depressed by neglect, entered into the sunshine of public favour and became one of the great universities in the Overseas Dominions of the British Empire.

The shock of the failure of the union movement in Nova Scotia paralysed the interest of the public in higher education and retarded for a generation university development in the Maritime Provinces. Nova Scotia established "Free" schools in 1864, Ontario in 1871. Within a score of years Ontario witnessed the State's full acceptance of its responsibility for higher, as well as elementary, education, while Nova Scotia, fifty years after its great achievement, blinded by sectarian strife, continued like Samson of old, grinding corn for others.

Three attempts were made to unite the colleges in Ontario; and three, if not four, types of union were considered. The first was made in 1843 by Robert Baldwin, who introduced a Bill to unite King's, Victoria, Queen's and Regiopolis, in a university like Oxford.[40] This university, to be called the University of Toronto, was to be

[39]Statutes of Nova Scotia, 1876; University of Halifax, 1878.

[40]University of Toronto, p. 36.

given the powers, functions and endowment of King's College. Each of the colleges was to receive a grant of £500 a year for four years. Thereafter they were to be maintained out of funds "set apart for religious purposes," probably the Clergy Reserves. Naturally Bishop Strachan protested most vigorously. The dissolution of the Legislature killed the bill.

The next attempt was made four years after the secularization of King's College. The Act of 1853[41] provided the framework in Toronto for another University of London, examining and conferring degrees upon men of every class and creed, who successfully met the prescribed educational tests. With this university sectarian colleges, no matter where situated, could be affiliated and share to some extent in its government.

All the colleges except Trinity, which Bishop Strachan had founded in protest against the secularization of King's, entered into affiliation, but none except University College sent up students for examination. This union remained barren of results.

Thirty years later, in 1883, the University of Toronto, which had hitherto been maintained out of the Land Grants, appealed to the Legislature for a grant. At once the denominational colleges protested, claiming that they too were doing university work, but had received no State aid since 1868. Out of the discussion came Mulock's appeal:[42] "Is it possible for this province to secure a university worthy of the name?" "Is there no way in which we can unite to this end?"

Goldwin Smith proposed a union like Oxford. The London idea had been tried and failed to satisfy. To bring the denominational colleges as a group of theological colleges around an Arts college maintained by the State demanded too many sacrifices of Victoria, Queen's and Trinity. Burwash proposed a transfer of Victoria and Queen's to Toronto, and a Federation of the three universities within Toronto, each suspending its degree conferring powers. As early as 1850 the permission of the Legislature had been given for the removal of Victoria to Toronto.

Though Queen's failed to come in, the Federated University of Toronto included the Universities of Victoria (and later of Trinity), St.Michael's College and the Theological Schools—Knox and Wycliffe. In affiliation were several professional and secondary schools.

The Federation of 1887 effected the transfer of the sectarian colleges to one centre, leaving to them the liberty of accentuating

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[41]University of Toronto, p. 36.

[42]Report Toronto University Commission, p. VIII, *et passim*.

their religious training, while enjoying all the facilities of a strong university properly equipped, maintained and controlled by the State.

The University of Toronto is a compromise born of the attempt of 1853, but it is a compromise that works and a compromise that has passed from a delicate balancing of opposing interests, to a strong and vigorous organism that is adapting itself to changing conditions and growing in strength and service with the passing of the years. In the Federation there is undisputed State control and State obligation; there is also denominational liberty and college autonomy. The University in its complexity suggests the present University of London, but in the thirty-five years of its existence it has achieved a unity of purpose and uniformity of method beyond the reach of London.

The State Universities

Whence came the idea of the State University to Canada? The idea of a State university implies more than State aid. It implies control by the State, and it implies an obligation on the part of the State to establish colleges or universities, without regard to private or Church initiative.

From the first the State recognized an obligation to aid the colleges. From the Provincial Treasury King's College, Nova Scotia, received an annual grant of £400; another £500 for a building. It also received an annual grant of £1000 from the Imperial Treasury. The New Brunswick College received 2000 acres, an annual grant of £200, and later £11,500 for buildings. For King's College, Toronto, 225,723 acres were set aside and an annual grant of £1000 was promised by the Home Government.

Grants in aid, annual or specific, is the usual form of support given by the State to universities in Great Britain, Australia, South Africa and India. Colleges are regarded as the creations of the Church or individual enterprise. The State expresses approval through a charter, and encouragement through a grant.

Though grants in aid imply an obligation on the part of the State to assist and encourage, they do not involve the admission that the State is responsible for the establishment and support of university education with or without the initiative and assistance of ecclesiastical or private enterprise.

The admission of that responsibility is not traceable to the British tradition. In Canada it first appeared in the Legislation establishing "Free Schools." Before that the State assisted and regulated public education but it did not recognize its obligation to provide the means of an elementary education for all the people. It was much later that it admitted its responsibility for compelling every child to avail himself of the education provided.

This conception of the State's obligation to educate its citizens is the corollary of the doctrine of democratic government. If the people have a right to govern they have also a duty to qualify for the exercise of government. The politician may exclaim, "We must educate our masters," but the people must accept the obligation to make the most of themselves through education if they demand the privilege of self-government. This humanitarian conception may be traced to the rights of man, which were proclaimed by Rousseau, formulated by Kant and set forth in the American Declaration of Independence. They gave dynamic to the French Revolution and intellectual justification to the American.

That the State University and the State School rest on the same basis is evident from the emphasis placed upon free tuition in school and university in many States of the Union and later in some of the Provinces of Canada. The British Columbia University Act of 1908 declared that instruction was to be free to all students in the Arts and Sciences. The Minister of Education in Saskatchewan, when discussing the proposed university, declared that the university, like the schools, should be free.

This admission of financial responsibility by the State for the university was first expressed in Western Canada in the University Ordinance of 1903, passed for the North West Territories, at the instance of Premier Haultain, in which the State reserved for itself the right to establish universities when necessary and thus notified the advocates of sectarian colleges that the State would reserve for itself a monopoly of degree conferring powers.

Elsewhere in Canada, prior to this, the State awaited the initiative of the Churches—in Manitoba no less than in Nova Scotia. But between the granting of the Royal Charter to King's, Nova Scotia, in 1802, and the N.W.T. University Ordinance of 1903, the people had learned that sectarian initiative and control led to sectarian strife and State embarrassment, and had come to realize that the State is in duty bound to open the door of education from the lowest to the highest grade, to all the people without respect to class, creed or race. State support is only one of the essentials in the idea of a State university. With support there must go control.

The earliest form of control was regulation. This was exercised through a Charter which conferred certain powers and duties. The State retained the right of inspection through a Visitor or commission.

Further, the State required an accounting for the grant in aid. This form of control was not very effective. Until abuses became notorious, the Visitor seldom intervened. If difficult conditions were attached to grants and inspectors became inquisitive and insistent, the university was irritated rather than guided, and made outcry against the curtailment of its freedom.

To-day the British universities, through economic causes, the rapid expansion of their numbers and expensive needs, are becoming more and more dependent upon Treasury Grants. The Parliamentary Grants Committee is exercising its authority with more vigour and possibly with less discretion. The universities, in consequence, are on the one hand clamouring for larger grants, and on the other protesting loudly against infringements of their ancient liberties.

There is much to be said on their side. Bureaucratic control is seldom sympathetic, rarely appreciative of the aims and difficulties of the distant local body and still more rarely patient and long suffering.

But, on the other hand, if the subject repudiates "Taxation without Representation," the State must deny "Support without Control." In Canada, State support of sectarian colleges embittered strife and wasted resources until in defence of self and of education the State had to assume control. This was done by the democratic governments which came after the granting of Responsible Government.

These governments at first administered the colleges through a department of government. To this day this method is followed in the administration of the Colleges of Agriculture in Nova Scotia, Ontario and Manitoba. It was the method followed in Toronto until 1906. The method of departmental administration opened the door to the suspicion of party patronage, an outrage to the traditions of university freedom.

The Toronto Act of 1906 changed all this. It (and in this it was followed by the Acts of Saskatchewan, Alberta, British Columbia and Manitoba) guaranteed the freedom of the university from both political and sectarian interference by placing its government in the hands of an independent Board of Governors, and by holding the President responsible for all academic appointments. Thus was the State university removed from the suspicion of political interference and the academic character of its staff guaranteed. Nevertheless, the strong and abiding safeguard of academic freedom is to be found only in the vigorous and enlightened opinion of the people from whom the university receives its support and whose interest it serves.

This account of the development of the support and the control of the universities in Canada does not reveal the origin of the idea of the State university. For this explanation we must go farther afield. In Ontario the idea of a State university first gained ascendancy. From Ontario it spread to the West. Ontario's nearest neighbour to the south, Michigan, was the first state to develop a State university in a striking manner.

Michigan was founded in 1837. Toronto's Royal Charter was amended the same year. Michigan began teaching in 1841; Toronto in 1843. Michigan, under President Tappan from 1852-63, blossomed out and became the leading university in the West. In 1849 the Province of Ontario changed the name of King's College to Toronto University and assumed full responsibility for it. That the success of Michigan had its effect upon Toronto is without doubt. The inquiries and report of the Toronto Commission of 1905 show how closely the development of the State universities in the American Union had been studied.

Whence came the idea of the State university to America? Thomas Jefferson is sometimes credited with introducing it from France into the University of Virginia. From his retirement from the Presidency in 1809 until his death in 1825 Jefferson was planning the buildings, gathering the Faculty and shaping the organization of the University of Virginia, or, as has been said, "anticipating all the great ideas of aim, administration and curriculum, that dominated the American universities at the end of the 19th century." [43]

What Jefferson emphasized was not the State college as opposed to the Church or private college, but the idea of the university as distinct from that of the college. The aim of the college was "to give a gentleman that broader and deeper culture with which custom demands he should be equipped." The aim of the university is to enlarge the boundaries of knowledge, to introduce students to new fields of learning and to train men for the professions. Jefferson assigned each branch of knowledge to a particular school with its own instructors. Within the university he established eight independent schools—ancient languages, modern languages, mathematics, natural philosophy, moral philosophy, chemistry, medicine, law—each in charge of distinguished men gathered from Britain and France as well as America. The rigid curriculum of the college was replaced by an elective system and sectarianism was banished from the university.

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[43]Encyc. Brit., vol. 15, p. 306.

Slosson, in the *Cyclopaedia of Education*,[44] asserts that: "The University of Michigan, remodelled in 1852 by President Tappan in accord with German ideals, became the pioneer and typical State University."

Some of the enthusiasm for the State university was doubtlessly kindled by the reports of what Von Humboldt had done through the University for Prussia, devastated and downtrodden by Napoleon. What the people of Prussia had lost by force of arms he undertook to recover by force of intellect. So successful was he that the King of France commissioned Victor Cousin, a peer of France and the most distinguished philosopher of his age, to report upon the state of Public Instruction in Prussia. This report excited a lively interest in England as well as in France. It captured the imagination of Crary and Pierce, who were responsible for the establishment and organization of the new University of Michigan. Hinsdale, in his history of that university, is credited with the statement that "it is no exaggeration to say that the single volume of this report that found its way into the oak openings of Michigan and into the hands of Crary and Pierce, produced results direct and indirect that surpass in importance the results produced by any other educational volume in the whole history of the country." [45]

It is worthy of note that the Report on Education,[46] which Dr. Duncombe presented to the Legislature of Upper Canada before the Act amending the Royal Charter of King's College was passed in 1837, contained extracts from Cousin's Report. Cousin's Report also came to the attention of Robert Baldwin, who, in 1849, transferred King's College from the control of the Church to the State. Egerton Ryerson knew it and adopted some of its ideas.

There is little doubt that the same enthusiasm for higher education, which had called colleges and universities into being in the United States, spread to Canada. As Duncombe says: "The spirit of reform is abroad and is reconnoitring the whole field of operation with a vigilance and an energy that declares unequivocally something must and shall be done. Nay, the work is already commenced, and as Lord Brougham declares, 'The schoolmaster is abroad.' Scotland has taken the lead, England is not far behind, Germany, Prussia and France follow close in their wake, and enterprising industrious America

[44]Cyclopaedia of Education, vol. 4, p. 664.

[45]Educational Problems, Univ. of Mich., p. 12.

[46]Duncombe's Report on Education to Legislature of Upper Canada, 1836, p. 9, p. 53, pp. 69-84, pp. 9, 53, 69-84.

has launched her pinnace, to 'contest for the palm with the Old World.'"[47]

But before Jefferson or Cousin caught the ear of the American people, the fundamental principle of the State University, the State's responsibility for the establishment, support and control of all branches of education was expressed in the Ordinance passed in 1787 by the Congress of the United States for the government of the North West. It made the following momentous declaration:[48] "Religion, Morality and Knowledge being necessary to good government and the happiness of mankind, schools and the means of education shall forever be encouraged."

Ten days later Congress also declared: "That Lot Sixteen in each township should be given for purposes of education and Lot Twenty-Nine for purposes of religion." It also affirmed: "That no more than two complete townships are to be given for the purpose of university education."

This statement of the people's faith in education and the generous provision for the realization of that faith in the new North West declare in clear and unmistakable terms the State's obligation for the institution, support and control of all forms of education, university no less than primary. The North West, for which the ordinance was passed, comprised the territory west of the Alleghanies, north of the Ohio and east of the Mississippi, and which was divided into the states of Ohio, Indiana, Illinois, Michigan and Wisconsin—territory which, by the way, was claimed as Canadian in 1782. In this North West and the newer and larger North West beyond the Mississippi, and north of the International Boundary line, the principle of the State's responsibility for all forms of education has been recognized as never before in the early history of any country in Europe or America.

In the century that followed,[49] more than one million of acres were reserved by the United States for universities and seminaries of higher learning, ten millions for agricultural and mechanical colleges, and another sixty-seven million for Common School purposes. As early as 1798 the Legislature of Upper Canada petitioned for the reservation of crown lands for educational purposes, and over one half million acres were set aside, one half of which ultimately went to King's College. In the University of Manitoba the Dominion set apart 150,000 acres in the eighties, and in 1908 the Legislature of

[47]Duncombe, p. 13.
[48]Thwing, p. 202; Educational Problems, p. 7.
[49]State Aid to Higher Education, Johns Hopkins University, 1898.

British Columbia authorized the appropriation of two million acres for the university. To this must be added the lands of the prairies, reserved for school purposes to the extent of two sections in each township, estimated at over 10,000,000 acres.

Beginning with Ohio's action in 1802 each state, as it was admitted into the union, usually proceeded forthwith to establish a State university. Similarly, in Western Canada, Alberta and Saskatchewan, within a year or two of their erection as provinces, organized and made liberal provision for State universities and, unlike the eastern provinces of the Dominion or the States of the Union, reserved for the State university the exclusive right to confer degrees except in divinity, to exercise university functions and to receive State aid for university purposes.

To the Prussian University has been traced that part of the conception of the State university which emphasizes service to the State; to the French and the Scottish that part which emphasizes knowledge or learning as the dominant aim; to the United States the idea of full financial responsibility.

Whence came the idea of control by the State? Not from Great Britain. There the universities are private corporations regulated and aided but not controlled by the State.

The New England colleges received charters and aid from the State and all went well until the preaching of Jonathan Edwards and Whitefield started the "New Light" movement which divided the people into warring sects. The activities of the S.P.G. in extending the Church of England, with its emphasis of the British connection, further divided the people. These sectarian disputes reached the Legislatures and attempts were made to control the colleges.[50] Yale established its independence as a private corporation in 1763, and the Dartmouth College case settled the dispute finally in 1819.

When the Royal Charter for King's College, New York, was sought in 1754, "one of the hottest disputes in the history of the colony" [51] broke out over the allotment of State funds to the college. The Governors had accepted from Trinity Church a gift of land with certain ecclesiastical conditions attached, such as: That the President should be a member of the Church of England; that the Archbishop of Canterbury and the Rector of Trinity should be members of the Board of Governors; that the use of the Liturgy of the Church of England should be obligatory, and that one professor of divinity should be of the Church of England. It was claimed by William

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[50]Brown: Origin of American State Universities, p. 19.

[51]Brown, p. 13.

Livingston that "instead of incorporating the college by Royal Charter it should be founded and incorporated by Act of Assembly, and that not only because it ought to be under the inspection of the civil authority, but also because such a constitution will be more permanent, better endowed, less liable to abuse and more capable of answering its true end." [52]

North Carolina in 1776 included in its State constitution the provision that "all useful learning shall be duly encouraged and promoted in one or more universities." In 1789 the State Legislature erected a university, which, however, did not come under direct State control until 1821. South Carolina, in 1801, erected a university under full State control. Brown, in his *Origin of the American State Universities*,[53] says that when "the repeated attempts to transform William and Mary College into an institution, which might fairly serve as the crowning member of a State system of education, had failed," Jefferson established the University of Virginia in 1819.

The action of Jefferson in turning from his old *Alma Mater* is significant. The College of William and Mary was the second of the nine pre-revolutionary colleges. Organized in 1693 by James Blair, who for fifty years fashioned it according to the best traditions of England and Scotland, it was for "eighty years the most civilized force in Virginia society."

"In the influences which helped to make Virginia a great State, the College of William and Mary, from its foundation to the outbreak of the Revolutionary War, filled a noble place. The personalities which prepared for that war, which carried it on, and which after the war helped to constitute a great Commonwealth, were largely graduates of William and Mary."[54]

In government, by president and professors, in the regulation of the life of its scholars, in the requirements of subscription to the XXXIX Articles, in the curriculum, and in the learning and character of its teachers, it "embodied the English tradition more fully than any other college."[54]

In wealth, in buildings, in teachers and in graduates, it was first among the pre-revolutionary colleges, and yet its inability or disinclination to respond to the new spirit of the age was responsible for its failure to retain the intellectual leadership of the nation.

Jefferson felt that the new spirit which animated the democracies of France and of America could not find expression in the old educa-

[52]Brown, p. 23.
[53]Brown, p. 35.
[54]Thwing, pp. 58, 64.

tional institutions fashioned for the few and controlled in the interests of caste or creed.

In the Imperial University of France, Napoleon, in 1808, presented a highly centralized organization of State instruction. Through the influence of Hamilton and Jay a similar idea was expressed in the University of the State of New York, which took over King's College in 1784, and controlled public education in that State.

In the Territory of Michigan in 1817 the same idea was expressed in that fantastic *Catholepistemiad*, with its thirteen Didaxiim or professorships, embracing all knowledge. Before the Territory reached the dignity of a State the *Catholepstemiad* had disappeared, but its fundamental idea of a "system of education supported by the people, and for the people, crowned by the University and providing for elementary training in all grades," reappeared in the Constitution of the New State, and in the "Organic Act" of the University of Michigan, both adopted in 1837.[55]

In these enactments the State assumed responsibility for the control of its university no less than for its establishment and support. Pierce, the father of the university, urged the State[56] to exercise its control by withholding charters from private colleges and denying them the privilege of conferring degrees. What he advocated in 1837 the Canadian Northwest Territories adopted in 1903.

The State of Michigan governed its University through a Board of Regents, of whom twelve were nominated by the Governor, with the approval of the Senate, and five were members ex-officio. The appointed Board has in several states been replaced by a Board elected by the people.[57]

In the Canadian State Universities the Boards are usually appointed by the Lieutenant-Governor-in-Council, though in Saskatchewan five out of eight Governors are elected by the University Senate, and in New Brunswick four are elected by the Alumni. Notwithstanding these exceptions it is universally recognized that the university is responsible either directly to the people or to their elected representatives.

From the colleges founded by the Churches primarily for religious purposes, university development in Canada has been traced to universities established, supported and controlled by the Provinces for public purposes. The main trend of this development has been from Church to State control and support. The one obvious

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[55]Shaw: University of Michigan, p. 6.

[56]Educational Problems, p. 6.

[57]Shaw, p. 20.

inference is, that the people, for whom and by whom all political and social institutions exist, have gradually asserted the claim that these educational institutions, which they have instituted and for which they are responsible, shall serve all the people and not a particular class or creed.

The liberty of the individual to worship as he wills and to learn as he wishes is subject to certain restrictions which the State imposes in the name of the public good. From the individualism of the eighteenth century the movement has been extensive and rapid. It is possible that in the course of time a reaction will set in against the claims of the community or the State to override the wishes and rights of the individual.

The Church college still exists and performs its functions independent of State aid and control. The Private University, equally independent and possibly equally indifferent to the aid and the control of the state, may serve a select community or group, according to their wishes; and if those wishes be wiser and better than those of the great mass of the people, its service may be of inestimable value to civilization.

No attempt has been made to appraise the relative merits of the Church, the Private and the State universities. To trace the historical development is not to determine ultimate worth. Only where long periods of time have provided many and varied tests can history attain to finality in its judgments of truth and value.

If "through the ages an increasing purpose runs," and if "the best is yet to be," then the tracing of the historical development of a movement or an institution may in some measure be an approach to truth and the ascertainment of value. For this the time is too short and the field too narrow since the founding of the first King's College in Canada in 1789, or the founding of Harvard in 1636. Even Padua, with its seven hundred years, and Europe with its many states and races, may fall short of the length of time, the importance and variety of the conditions required for the attainment of even a moderate degree of certainty in knowledge and finality in judgment.

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SECTION III

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The Mechanism of the Catalysis of Hydrogenation by Nickel

By MAITLAND C. BOSWELL

It is a well known fact that many compounds containing unsaturated carbon atoms will, when heated along with gaseous hydrogen to relatively high temperatures, combine with hydrogen to form saturated compounds. Thus a mixture of ethylene and hydrogen passed through a tube heated at 550°C. forms ethane. Sabatier (1) discovered that metallic nickel prepared by the reduction of nickel oxide by hydrogen at a temperature below 300°C. is an excellent catalyst for this reaction, and that in its presence ethylene and hydrogen will combine with appreciable velocity at room temperatures, while at 150°C. the velocity of combination is very great. Sabatier and his students and other investigators have extended this catalytic hydrogenation by nickel to a great variety of unsaturated compounds. Among these processes which have assumed a large commercial importance is the hydrogenation of unsaturated fats, the so-called hardening of fats process, whereby the liquid fat olein present in such liquid fats as cocoanut oil and cottonseed oil is transformed into the solid fat stearin.

The investigation, which is the subject of this paper, has for its object the determination of how the nickel functions in these hydrogenations,—the mechanism of the reactions.

As the numerous investigations on this subject have already been dealt with exhaustively elsewhere, there is no necessity here to do more in this regard than to review very briefly the outstanding conclusions which have been arrived at by previous investigators. Later in the paper these conclusions will be reconsidered and the endeavour made, from the experimental data obtained in this laboratory, to show that some of the apparently contrary conclusions from former researches can be reconciled, and brought into conformity with another representation of the mechanism which is here proposed.

Several investigators have measured the capacity of nickel and other metals to absorb hydrogen and have connected this with the catalytic activity of nickel in hydrogenation, the hydrogen being supposed to exist in the nickel in some specially active condition, so that from this standpoint the nickel acts as a hydrogen carrier.

Sabatier (2) postulates the existence of definite hydrides of nickel, NiH_2 and $\begin{matrix} Ni-H \\ \| \\ Ni-H \end{matrix}$, which, giving up their hydrogen to unsaturated compounds, are changed into elementary nickel, which once more combines with free hydrogen to reform the hydrides. Here also, as in the former view, the nickel acts as hydrogen carrier. However, Sabatier replaces the conception of hydrogen activated by solution or absorption in the nickel, by the idea of hydrogen temporarily fixed in the form of definite hydrides of nickel holding hydrogen in a very labile or active condition. It is of interest to observe, in view of what will be pointed out later in this paper, that Sabatier expressed his belief in the formation of two hydrides, differing in the ease with which they give up their hydrogen, because of the experimental fact that nickel, prepared by the reduction of the oxide at a low temperature, varies in its activity, the more active form, which Sabatier believed to be NiH_2, is able to hydrogenate benzene while the less active form to which Sabatier ascribed the formula $\begin{matrix} Ni-H \\ \| \\ Ni-H \end{matrix}$ is unable to hydrogenate benzene but has the capacity of hydrogenating hydrocarbons of the ethylene series and other more easily hydrogenated compounds.

Wieland like Sabatier, believes in the intermediate formation of a hydride but goes a step farther in the picture of mechanism by indicating the existence of a loose addition compound between the hydride and the unsaturated compound, which unstable complex then breaks up with the formation of the hydrogenated compound and the regeneration of elementary nickel, which latter then reforms the hydride, and so the cycle of reactions continues.

Titoff and also Firth from measurements of the adsorption of hydrogen by various charcoals, were led to the conclusion that hydrogen is contained in charcoal in two states, one as a surface condensation of the gas which he designates adsorption, and the other as absorbed or dissolved hydrogen. It is the former adsorbed hydrogen which is believed to be active in effecting hydrogenations.

Fokin (3) found that in electrolytic reductions at the cathode that only those metals used as cathodes were effective in reductions electrolytically, which were found active in hydrogenation with ordinary hydrogen by the Sabatier method. Fokin believes that the special capacity of these metals to effect cathodic reduction is due to occluded hydrogen, the order of activity being also the order of capacity for occluding hydrogen. Fokin ascribes the activity of nickel in hydrogenation to the occluded hydrogen which he believes to exist in the metal partly in the monatomic condition.

Ipatiew (4) discovered that many organic compounds could be reduced by hydrogen at high pressure using nickel oxide as catalyser instead of reduced nickel.

Bedford and Erdmann (5) prepared a nickel oxide in a very finely divided and voluminous condition by igniting in a muffle a concentrated aqueous solution of nickel nitrate mixed with sucrose. The resulting mass, which Erdmann believes is nickel oxide, is said to be more active than reduced nickel in effecting hydrogenations. Erdmann expresses the opinion that the activity of reduced nickel as ordinarily used in the hydrogenation process is due to the presence of a sub-oxide of nickel. This contention has been combated by Normann (6) and others, and has given rise to an interesting controversy which has resulted in the accumulation of considerable new data regarding the relative activities of nickel oxide and reduced nickel in hydrogenations, and the presence or absence of sub-oxide in reduced nickel. No definite conclusions regarding the main point under discussion, viz., whether metallic nickel or an oxide of nickel is the active agent, appears to have been reached. Later in this paper, the reason for this confusion will be pointed out and the belief advanced that it is neither metallic nickel nor nickel oxide that is active in hydrogenations.

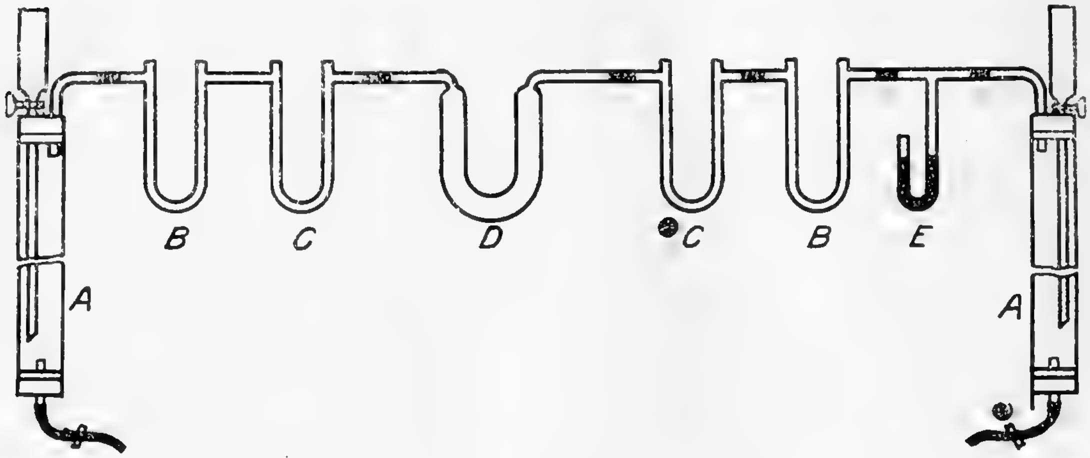
The experimental data of this paper, together with the observations of other investigators, has led to the conclusion that nickel oxide reduced by hydrogen at 275° to 300°C. consists, at the surface, of elementary metal carrying a surface film of dissociated water in the form of charged hydrogens and hydroxyls. This may be represented thus:

$$\text{(Ni)}\left[\begin{array}{l} H^+ \\ OH^- \\ H^+ \\ OH^- \\ \vdots \end{array}\right.$$

As will be seen from the experimental data, the matter is complicated by the fact that the reduction of all the NiO at 275° to 300°C. to form the above complex is very difficult. Even after ten hours' reduction there is still unchanged NiO which slowly undergoes reduction to form more and more complex.

EXPERIMENTAL

In the experiments here described the following apparatus was employed except for the alterations noted in some cases.



AA are gas burettes. BB are guard tubes containing sulphuric acid on pumice. CC, also containing sulphuric acid on pumice, were the tubes weighed in water determinations. D is the tube holding the catalyst. E is a small manometer.

Experiment 1.

A quantity of nickel nitrate was ignited. Two grams of the resulting oxide was dissolved in nitric acid and the solution evaporated to dryness on the water bath. This nitrate was dissolved in a little water, and asbestos, which had been purified by extraction with acids, washing and ignition, was added. This asbestos holding nickel nitrate was placed in a quartz tube in a combustion furnace and heated to a high temperature. The quartz tube containing the nickel oxide on asbestos was placed in the apparatus train in place of the U tube *d* and heated in an air bath at 275°C. Electrolytic hydrogen, purified by passage over heated copper gauze and then through sulphuric acid dryers, was then passed through the apparatus. The following results were obtained:

REDUCTION OF NICKEL OXIDE AT 275°C.

Time	*Weight of water in grams*
½ hour	0.0742
½ "	0.0280
1 "	0.0446

Time	*Weight of water in grams*
½ "	0.0280
½ "	0.0158
½ "	0.0126
½ "	0.0126
1 "	0.0306
1 "	0.0152

The nickel was allowed to stand at room temperature in an atmosphere of hydrogen over night. Upon again passing hydrogen at 275° the following results were obtained:

Time	*Weight of Water in Grams*
1 hour	0.0410
1 "	0.0038
1 "	0.0052
1 "	0.0040

It will be observed that a relatively large amount of water was given off during the first hour after standing in hydrogen at room temperature over night.

The nickel was once more allowed to stand in an atmosphere of hydrogen at room temperature over night and on the following morning nitrogen was passed at room temperature.

Time	*Water obtained in grams*
1 hour	0.0252
½ "	0.0018

The tube containing nickel was now heated in a combustion furnace to full heat of the gas burners and nitrogen again passed. In two hours only .0076 g. of water was obtained. Here again it is observed that the water obtained during the first hour after standing over night in an atmosphere of hydrogen is relatively large.

That considerable oxygen still remained on the nickel was proven by passing hydrogen at the full heat of the furnace when 0.1040 g. water was obtained.

There are two explanations for the large amount of water obtained after standing over night at room temperature in an atmosphere of hydrogen: (1) hydrogen is adsorbed by the nickel on reduction of the oxide and this adsorbed hydrogen, being larger in amount at low temperature, reacts more rapidly with unchanged oxide in the interior of the particles, even at room temperature, and (2) that water vapour formed by the reduction of oxide at 275°C. is adsorbed on the nickel and this water is given off on cooling.

Experiment 2.

In order to decide this the nickel on asbestos was oxidized by free oxygen at a red heat and then reduced at 275° by hydrogen for five hours. The water obtained during the first half hour was 0.0779 g. and in the last half hour 0.0060 g. One end of the quartz tube was then closed and the other end connected with a vacuum pump and the tube heated for one hour at the full heat of the combustion furnace under a high vacuum. It was then cooled and held under suction for a further forty-five minutes and the water adsorption tube weighed. The water obtained amounted to only .0018 g. Thus the adsorbed hydrogen had been expelled almost completely without effecting any further reduction. Hence the water obtained in the above experiments after standing over night in relatively such large amounts is not due to water vapour adsorbed on the nickel but to adsorbed hydrogen which slowly removes more oxygen from that remaining in the nickel.

The reduction of nickel oxide at 275° was again performed, the reduction being carried out for a longer time, with the following results:

Time	*Water in Grams*
1 hour	0.0704
½ "	0.0430
½ "	0.0428
½ "	0.0110
½ "	0.0166
½ "	0.0086
½ "	0.0074

The tube was then rapidly cooled with cold water and hydrogen again passed at 275°.

Time	*Water in Grams*
½ hour	0.0158
½ "	0.0000

The cooling and reheating was repeated when at 275° for ½ hour. 0.0092 g. water was obtained.

The apparatus was allowed to stand over night and hydrogen passed at 275° on the following day.

Time	*Water in Grams*
½ hour	0.0500

The tube was cooled and then again heated at 275°.

Time	*Water in Grams*
½ hour	0.0500
½ "	0.0016

Cooled again and heated to 275°

½ hour	.0066
½ "	.0038

Cooled and allowed to stand two hours and heated at 275°.

½ hour	.0134
½ "	.0006

Finally the apparatus was allowed to stand corked up for three days along with the hydrogen remaining in the tube. Upon now passing hydrogen at room temperature for one hour 0.0323 grams water was obtained.

There was still considerable oxygen remaining for on passing, at the end of the experiment, hydrogen at 600°C. .1214 g. water was obtained.

It is evident from this series of experiments that when nickel oxide is reduced by hydrogen, the reduction occurs in two ways: (1) surface nickel oxides are reduced leaving adsorbed hydrogen on the nickel, and (2) the adsorbed hydrogen slowly reacts with the remaining nickel oxide. It would also appear that this adsorbed hydrogen is held, not only on the outer surface of the nickel, but on the inside of particles for even after prolonged reduction there is still a relatively large amount of water evolved on standing. It is also evident that this hydrogen reacts to form free water only very slowly.

Experiment 3.

The object of this was to determine the amount of hydrogen taken up at room temperature after nickel oxide has been reduced by hydrogen. Nickel oxide was reduced for three and one half hours at 275°C. During the last half hour of this period 0.0076 g. water was obtained. On standing over night in hydrogen at room temperature 75 c.c. of hydrogen was found to have been taken up. In five hours more the pressure of hydrogen indicated a continuous adsorption of hydrogen.

This experiment was repeated when it was found that 40 c.c. hydrogen was taken up during the night at room temperature. This observation appears to be in harmony with that of Ross, Culbertson and Parsons (7) who state that "at ordinary temperature hydrogen is adsorbed in active nickel to a considerably greater extent than in cocoanut charcoal." However, as will be shown presently, this should, strictly, not be called adsorbed hydrogen.

This experiment in conjunction with the latter part of experiment (1) indicates that at room temperature, the amount of adsorbed hydrogen being greater than at 275° the amount of action of adsorbed hydrogen on the remaining nickel oxides, is relatively large, notwithstanding that the temperature is lower. This would indicate that the effect of adsorption of hydrogen on the reductions is large in comparison with the effect of temperature.

Experiment 4.

It was hence desirable to determine whether hydrogen is adsorbed during the reduction of nickel oxide at 275°C.

3 grams of nickel oxide, without any asbestos, was placed in the tube *d*. Hydrogen was first passed through the apparatus disconnected from the burettes, at room temperature for one hour, the tubes *c c* having been weighed full of nitrogen beforehand. The burettes containing a measured volume of hydrogen were now connected with the system and the reading of the burettes taken. The tube *d* was now heated to 275°C. and hydrogen passed back and forth for one hour. At room temperature the volume of hydrogen used up was determined. In this case 980 c.c. The burettes were disconnected and nitrogen passed for one hour at 120°C. to drive over all the water formed in the reduction. 0.6894 g. water was obtained. This is equivalent to 920 c.c. hydrogen. Thus, about 60 c.c. of hydrogen was adsorbed during the reduction to this stage.

A similar experiment gave water equivalent to 380 c.c. of hydrogen with an adsorption of 45 c.c. for the set of conditions under which this reduction was carried out.

Thus, when nickel oxide is reduced at 275°C. hydrogen is adsorbed in very considerable amount over and above the hydrogen used to form water. On cooling to room temperature and allowing to stand several hours in hydrogen very much more is adsorbed, the first portion adsorbed at 275° having gone to reduce more of the nickel oxide. On now heating to 275° in hydrogen relatively very little water is obtained because most of the hydrogen previously adsorbed has been used up in reducing nickel oxide, the resulting water being evolved, and also because the adsorption at 275° on nickel alone, without the accompaniment of reduction of nickel oxide, is small.

Experiment 5.

This experiment was performed in order to determine the following:

(1) Does this adsorption of hydrogen during the reduction of nickel oxide continue after long reduction?

(2) Is it possible to reduce nickel oxide so that it loses all its oxygen, by heating at 275° in a current of hydrogen?

(3) Will the product of the reduction of nickel oxide at 275° by hydrogen and containing a considerable amount of adsorbed hydrogen, hydrogenate ethylene alone at 150° in the absence of free hydrogen?

(4) Will the product of the lengthy reduction of nickel oxide by hudrogen at 275° catalyse the hydrogenation of ethylene by free hydrogen?

In this experiment approximately 2½-3 grams of nickel oxide on asbestos was placed in tube *d* of the apparatus. The air in the apparatus was displaced by hydrogen in the cold and the burettes filled with a measured volume of hydrogen. The hydrogen was passed back and forth, the tube *d* being heated to 275°C. and the water evolved measured at intervals of 24 hours after cooling to room temperature. Care was taken to exclude air from the apparatus during the disconnection and connection of the U tubes. Following are the results obtained:

H at start	H at end	H disappeared	H_2O evolved	H equiv. of H_2O	H adsorbed
c.c.	c.c.	c.c.	grams	c.c.	c.c.
735	115	620	.4064	545	75
395	330	65	.0484	65	0
330	250	80	.0451	60	20
250	155	95	.0228	30	65
155	90	65	.0115	15	50
350	260	90	.0230	30	60
345	250	95	.0340	44	51
385	320	65	.0307	40	25
250	165	85	.0305	40	45

Thus, after nine days' reduction at 275°, hydrogen is still adsorbed in considerable quantity over and above the hydrogen required to form the water evolved. It was also found that there was the same relatively large disappearance of hydrogen on standing at room temperature each night. Hydrogen was passed back and forth for one hour every morning at room temperature in order to carry over the water evolved during the night. The volumes under the headings "H at end c.c." corresponds to the reading on the burettes each morning after this passage back and forth for one hour at room temperature. Evidently after nine days' reduction there is still considerable oxygen remaining on the nickel for .0653 g. of water was evolved on reduction after that period.

A measured volume of ethylene prepared by the action of phosphoric acid on ethyl alcohol by the method of Newth and which, upon analysis, showed 98.5 per cent. ethylene, was passed back and forth at 150°C. for two hours, the apparatus having previously been filled with nitrogen. There was no change in volume and analysis showed that no ethane was formed.

A mixture of ethylene and hydrogen of known composition was then passed for one hour at 150°C., the apparatus having been filled wirh nitrogen.

Composition of the gas at outset

Ethylene	215 c.c.
Hydrogen	95 c.c.
Nitrogen	254 c.c.
Vol. of gas at end of experiment	464 c.c.

Composition of gas at end.

Ethylene	28.4%
Ethane	16.8%
Hydrogen	0.0
Nitrogen	54.8

Therefore, ethane produced equals $.0168 \times 464$ c.c. = 77.9 c.c.
and ethylene remaining $.0284 \times 464$ c.c. = 131.8 c.c.

Therefore, ethylene used up $= 215 - 131.8 = 83.2$ c.c.

Now, hydrogen used in forming ethane = 77.9 c.c.

But 95 c.c. hydrogen disappeared in all.

Therefore, $95 - 77.9 = 17.1$ c.c. hydrogen was used up in some other way, except in the hydrogenation of ethylene.

Now the early experiments of this paper have shown that this amount of hydrogen is much greater than would have been used up in the same time by treatment with hydrogen alone of a nickel complex which had received the same lengthy reduction. The conclusion seems justified that this relatively large disappearance of hydrogen in excess of that used in hydrogenating ethylene, was not due to reduction of unchanged nickel oxide.

It is equally unsatisfactory to say that adsorbed hydrogen on the nickel complex has been used up in effecting reduction of ethylene, and that free hydrogen has simply become adsorbed hydrogen by taking the place of this hydrogen which has reacted. For it is difficult to see, from this standpoint alone, why the reaction with ethylene of hydrogen already absorbed by nickel, should cause the adsorption of a much larger volume of hydrogen than has reacted with the ethylene. Moreover, were this explanation correct, one would certainly expect to find a nickel complex, carrying a considerable amount of adsorbed hydrogen, able to effect, to a measurable extent, the hydrogenation of ethylene at 150°C., in the absence of free hydrogen. Experiment (5) has shown that such is not the case.

It seems a more satisfactory explanation to say that free hydrogen has reacted, not only with the ethylene but with something on the surface of the catalyser complex other than unchanged nickel oxide. The conclusion is almost unavoidable, that oxygen in some active form (possibly as negative hydroxyl groups, accompanied by positive hydrogens) is present on the nickel surfaces, formed by the reduction of nickel oxide at temperatures below 300°C., and that it is with this special form of oxygen that the relatively large amount of hydrogen, which disappeared in experiment (5), reacted.

Confidence in this view is further increased by the fact, demonstrated in experiment 10, that a nickel, free from oxygen, is a poor catalyst for hydrogenations, and also by the fact that as a normal nickel catalyser loses its oxygen, which it slowly does during hydrogenations, it also gradually loses its catalytic activity, while a nickel free from oxygen and carrying hydrogen alone, is almost useless as a catalyst for hydrogenations.

All these facts taken in conjunction point very strongly to the conclusion that the reaction of hydrogen with ethylene is not only accompanied by reaction of hydrogen with this special form of oxygen, but that these two reactions are mutually dependent and simultaneous reactions.

The writer suggests as a mechanism for hydrogenation, by a normal nickel catalyser, the reactions given at the conclusion of experiment 7. These four reactions seem to furnish an adequate picture of the facts referred to above, as well as of the others dealt with later in this paper. According to this mechanism the complex, formed by the partial reduction of nickel oxide, which is active in catalysing hydrogenation, consists of nickel oxide particles covered by nickel surfaces carrying negative hydroxyl groups and positive hydrogens, as represented in the following constitution, where only one layer of hydroxyls and hydrogens is shown.

$$(NiO)_x.Ni \left| \begin{array}{l} \text{—} \\ H+ \\ OH- \\ H+ \\ OH- \\ \vdots \\ \text{—} \end{array} \right.$$

Taylor and Burns (8) express the general opinion that adsorption in the case of metal catalysts is a surface phenomenon, somewhat chemical in character, possibly involving re-arrangements of electrons in both the adsorbent and gas. The mechanism brought forward in this paper is a picture of such a surface phenomenon. However, Taylor and Burns also express the opinion that because the disappearance of catalytic activity is accompanied by suppression of adsorptive power, therefore the varying adsorptive capacity of the material accounts for the variable catalytic behaviour, thus connecting the catalytic capacity directly with adsorption of hydrogen alone. That this is not a complete picture of the mechanism seems clear from the experimental facts cited above and the argument based upon them. It may further be pointed out, that in the reduction of nickel oxide, and also in the hydrogenation of ethylene by a partially reduced nickel oxide, a condition is reached after long action, where the negative hydroxyls on the nickel, being slowly used up by reaction with hydrogen, are replaced with increasing slowness from the underlying nickel oxide. The surfaces approach more and more the condition of nickel carrying positive and negative hydrogens alone. Now if the catalysis of the hydrogenation of ethylene depends primarily on the presence of negative hydroxyls on the nickel surfaces, evidently a diminution of these would produce a falling off in the velocity of hydrogenation. Thus, although adsorption of hydrogen does occur as represented in reactions (2) and (4) under experiment 7, and although a falling off in adsorption of hydrogen accompanies diminution of catalytic activity, yet the adsorbed hydrogen is not primarily the active agent in hydrogenation with a normal nickel catalyser, but the negative hydroxyls, acting according to the mechanism represented under experiment 7.

The gas in the apparatus was replaced by nitrogen and ethylene passed back and forth between the burettes *aa* at 150°C. No ethane was formed.

Experiment 6.

10 litres of a mixture of hydrogen and ethylene was now passed at 150°C. over the catalyst from the last experiment. A careful

experiment controlled by analysis was now performed with this catalyst which had now activated a considerable union of ethylene and hydrogen. The mixture consisted of hydrogen 90 c.c., ethylene 180 c.c., nitrogen 300 c.c. Temperature 150°C. Time $\frac{1}{2}$ hour.

Volume of gas at beginning	570 c.c.
Volume of gas at end	500 c.c.
Reduction of volume	70 c.c.

Composition of gas at end

Ethylene	29%
Hydrogen	5.6%
Ethane	5.4%
Nitrogen	60%

Water obtained = 0.0164 g. = 22 c.c. hydrogen.

Therefore, hydrogen present at end $= \frac{5.6}{100} \times 500 = 28.0$ c.c.

hydrogen used up $= 90 - 28.0 = 62.0$ c.c.

ethylene present at end $= \frac{29}{100} \times 500 = 145$ c.c.

Therefore, ethlyene changed to ethane is equal to $180 - 145 = 35$ c.c.

" 35 c.c. hydrogen was used in hydrogenating ethylene to ethane.

But 62 c.c. of hydrogen disappeared.

Therefore, $62 - 35$ c.c. hydrogen was used in some reactions other than hydrogenation of ethylene = 27 c.c.
Water formed in this reaction = 0.0164 g.
equivalent to 22 c.c. hydrogen.

Therefore, in this case the hydrogen used up in excess of that used in the hydrogenation of ethylene was transformed for the greater part into water. This amount of water could not have formed by the very slow reaction of the adsorbed hydrogen on the unchanged nickel oxide, as has already been shown. It probably comes from the hydroxyl groups in the surface film on the particles.

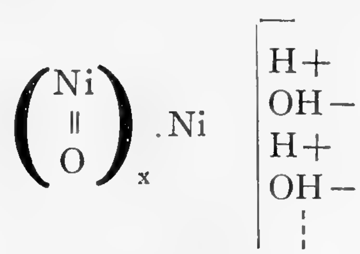
Here again the hydrogen used up in excess of that required for hydrogenation of ethylene, is relatively large, and is very much greater than would have disappeared in one half hour treatment of the same nickel complex with hydrogen alone. Moreover, the equivalent of this excess hydrogen was almost all evolved in the form of free water. There accordingly was only a small amount of this excess hydrogen remaining on the catalyser as adsorbed hydrogen. Once more the conclusions arrived at under experiment (5) seem to be confirmed.

Experiment 7.

It was of interest to know whether unreduced nickel oxide is active or not for catalysing the union of ethylene with hydrogen. The nickel material was accordingly heated with oxygen for a long time at 240°C. The free oxygen was expelled by nitrogen and a mixture of 210 c.c. hydrogen and 95 c.c. ethylene passed at 150°. For half an hour there was only a small change in volume and it appeared that the action was going to be very slow when suddenly a reduction in volume of 95 c.c. occurred, and simultaneously water was seen to pass over into the absorbers. In other words, there was no indication of hydrogenation until there was evidence of reduction. Nickel oxide cannot catalyse the union of hydrogen and ethylene until some reduction has occurred, which, as has already been pointed out, is accompanied by the absorption of hydrogen to form a hydrogen-hydroxyl complex on the surface of the particles. This experiment was repeated with exactly the same observations.

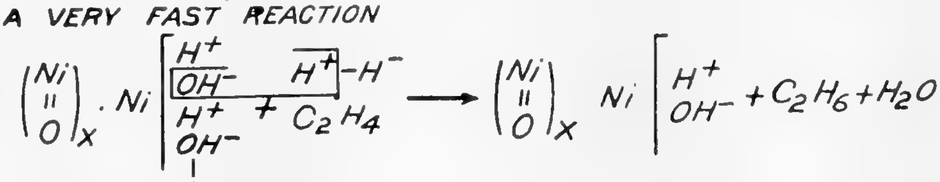
This experimental data appears to receive an adequate representation by the following mechanism:

Nickel oxide partially reduced at a low temperature consists of particles of nickel oxide surrounded by metallic nickel carrying positive hydrogens and negative hydroxyls alternately arranged on the surface in several layers, thus with only one layer of hydrogen and hydroxyls represented—

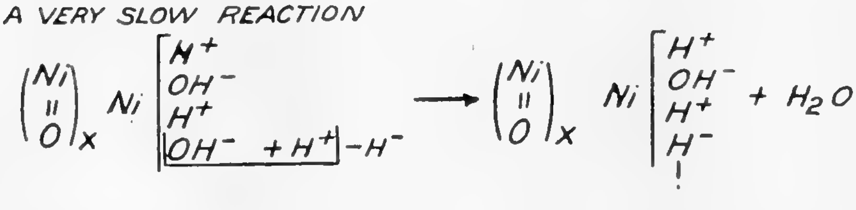


When this complex catalyses the union of hydrogen and ethylene four reactions occur:

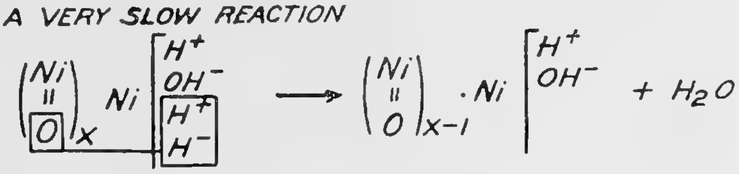
1 A VERY FAST REACTION



2 A VERY SLOW REACTION



3 A VERY SLOW REACTION



Reaction (1) represents the main reaction which occurs. It expresses the mechanism of hydrogenation by an active nickel catalyser.

Reaction (2) represents the slow removal of negative hydroxyls from the surface of the catalyser and the adsorption of hydrogen constantly taking place.

Reaction (3) represents the slow reaction of this adsorbed hydrogen with the unchanged nickel oxide in the interior of the particles.

A fourth reaction also occurs, involving the addition of positive and negative hydrogens from neutral hydrogen molecules to the complex on the right hand side of reaction (1), to form the complex on the left hand side of reaction (3). This fourth reaction represents the mechanism of hydrogen adsorbtion.

Equations (2) and (3) also represent the reactions which occur on continued reduction of nickel oxide by hydrogen. This continues until all the nickel oxide in the interior of the particles has been reduced and until finally all the hydroxyls on the surface have been removed and only adsorbed hydrogen, as positive hydrogens and negative hydrogens, remains. Thus the hydrogen which is taken up in excess of the equivalent of water formed is held on the surface in two ways: (1) as positive hydrogens and negative hydroxyls, and (2) as positive hydrogens and negative hydrogens.

Evidently the water represented in these equations is not all evolved for if such were the case the catalyser would soon lose all its oxygen and, as will shortly be pointed out, lose almost entirely its capacity for catalysing hydrogenations. This water is only evolved in the free state in relatively small amount, the chief part remaining on the particles as hydrogens and hydroxyls. This is equivalent to saying that in reaction (1) a negative hydroxyl on the surface of the catalyser has a tendency to unite with a positive hydrogen of a neutral hydrogen molecule, thus loosening the bond between the positive and negative hydrogens of the hydrogen molecule sufficiently to permit the positive and negative hydrogens of the hydrogen molecule to unite with a molecule of ethylene. That is the hydrogenation is pictured as occurring primarily at the surface of the particles by means of oscillating hydrogen atoms which are at one instant more closely associated with the hydroxyls and hydrogens on the surface of the particles and at the next instant more closely associated with each other in hydrogen molecules. A small portion of the impacts of positive hydrogens of gas molecules and negative hydroxyls on the surface result in the permanent formation of molecules of water which are evolved as such. This view is further confirmed by experiment 8.

Reaction (2) represents a reaction very slow in comparison with reaction (1) and which is constantly taking place during the hydrogenation. Negative hydroxyls on the surface are constantly and very slowly being removed and hydrogen being adsorbed.

Reaction (3) represents the reaction of this adsorbed hydrogen with unchanged nickel oxide in the interior of the particles. Here also the water represented is not all evolved in the free state but partly goes to reform hydrogens and hydroxyls on the surface.

Finally, after long use the oxygen remaining on the catalyser either as negative hydroxyls or unchanged nickel oxide in the interior becomes very small and nothing remains finally but nickel particles with adsorbed hydrogen thus—

$$\mathrm{Ni}\left|\begin{array}{l} - \\ H+ \\ H- \\ H+ \\ H- \\ \vdots \end{array}\right.$$

As we shall see, nickel in this condition is a very poor catalyst for hydrogenations. The activity of the catalyst is associated with its oxygen content and its activity can be restored by reoxidation and partial reduction.

Experiment 8.

If this explanation is correct it should be possible to catalyse the union of ethylene and hydrogen, i.e., bring about reaction 1 which is fast, without causing any appreciable changes by reactions 2 and 3, which are relatively much slower reactions, if the mixture of ethylene and hydrogen is left in contact with the catalyst for only a short time. Accordingly the catalyst was again oxidized by oxygen and reduced at 275° by hydrogen for eight hours and the hydrogen displaced by nitrogen. Mixtures of hydrogen and ethylene were successively passed back and forth over the catalyst, each mixture being in contact with the catalyst for only 15 to 20 minutes. The hydrogen used up and the ethane formed were determined. The results of three separate experiments are shown in the following table, calculated to nitrogen free gases:

Composition of gas c.c. C_2H_4	H	Vol. at start c.c.	Vol. at end c.c.	Reduction in vol.	Analysis of gas at end C_2H_4	C_2H_6	H_2	Hydrogen gone to ethane	Additional Hydrogen disappeared
200	135	335	200	135	36.3	63.7	0.0	127	8
195	110	305	195	110	45.7	54.3	0.0	106	4
105	195	300	195	105	0.0	52.4	47.6	195	0

These results in conjunction with the previous experiments show that in the hydrogenation of ethylene reaction (1) occurs at the outset by the loosening of the bonds between the positive and negative hydrogens of neutral hydrogen molecules. This is accomplished by the attraction of negative hydroxyls on the nickel complex for positive hydrogens of hydrogen molecules, without actually combining to form water. Had the hydroxyls been removed in experiment 8, then hydrogen would have been adsorbed according to reaction (4) and hence hydrogen would have disappeared in excess of ethylene hydrogenated. Thus the oscillation of a positive hydrogen atom between a negative hydroxyl group of the nickel complex and a negative hydrogen, is the initial cause of the catalysis of hydrogenation. In experiments (5) and (6), which were carried out more slowly, reactions (2), (3) and (4) took part to a greater extent, thus resulting in the disappearance of an excess of hydrogen over that required to hydrogenate the ethylene which disappeared.

Experiment 9.

That hydrogen is slowly adsorbed at room temperatures by a nickel catalyst was shown by filling the apparatus after experiment 8 with hydrogen and allowing to stand for four days at room temperature, readings of volume being taken at intervals.

Time elapsed	*Burette reading*
0	325 c.c.
3 hours	315 "
19½ "	310 "
3 "	310 "
22 "	300 "
18 "	290 "

On now passing nitrogen, water was obtained equivalent to 27 c.c. of hydrogen. Since at the commencement of this experiment the nickel catalyst was prepared by a long treatment with hydrogen the surface had probably reached an equilibrium condition, where the surface of the particles consisted of hydrogens and hydroxyl groups, as represented on the left-hand side of equation (1). This slowly reacted with hydrogen, according to reaction (2) so that water closely equivalent to the hydrogen used up was given off. There was some hydrogen in excess of the amount equivalent to the water given off. According to the above method of representation, this was due to the slow action of $H^+ H^-$ diffusing into the interior and reducing some nickel oxide, this hydrogen, which has left the surface, being replaced by more hydrogen. This union of diffused hydrogen and nickel oxide gives off water very slowly. Hence under the conditions of the experiment a small amount of hydrogen, used up in excess of the equivalent of water formed, was to be expected.

Experiment 10.

Nickel oxide reduced by hydrogenation at 400°C. is said by Willstätter (9) to be inactive. It was of interest then to determine the condition of the nickel with respect to hydrogen and oxygen content when prepared under these conditions.

A nickel catalyst was made by distributing 1.5 g. nickel oxide over 10 grams of finely divided asbestos by igniting the asbestos impregnated with nitrate. In this way a small amount of nickel oxide was distributed over a large surface. This was contained in the tube *d* of the apparatus already described. The apparatus was filled with hydrogen at room temperature. A measured volume of hydrogen was passed back and forth at 400°C., the tube *d* being heated in a bath of fused sodium nitrite, that part of the tube *d* containing the asbestos being completely immersed in the nitrite bath. Hydrogen was passed for 20 hours.

Hydrogen disappeared..............	410 c.c.
Water evolved equivalent to........	380 c.c.
Hydrogen in the catalyst...........	30 c.c.

This catalyst adsorbed very little additional hydrogen on standing for three days. Thus this inactive nickel does contain adsorbed hydrogen. Since all the oxygen has disappeared this catalyst, according to the above method of representation, consists now of:

$$\text{Ni}\left|\begin{array}{l} H+ \\ H- \\ H+ \\ H- \\ H+ \\ \vdots \end{array}\right.$$

i.e. nickel carrying positive and negative hydrogens on the surface of the particles. It might be desirable to restrict the term 'adsorbed hydrogen' to this complex carrying hydrogen alone.

The apparatus was now filled with nitrogen. On now heating the catalyst at 400°C. with oxygen for four hours, only 50 c.c. of oxygen disappeared. This indicates a marked difference between this nickel and nickel prepared by reduction at 275°.

The above catalyst was now reduced at 275° for seven days and its activity determined with a mixture of ethylene and hydrogen in the manner already described. No action occurred up to 120°C., when a slight reduction in volume took place after passing the gases for $1\frac{1}{2}$ hours. A gas analysis showed, however, no formation of ethane. At 150° reaction set in very slowly. It required one hour to accomplish the union of 100 c.c. hydrogen with 100 c.c. of ethylene.

Thus the original reduction at 400° rendered the catalyst very much less active than the normal catalyst prepared at 275°. It took up oxygen with difficulty, and in small amount, and upon reduction of this oxidized nickel at 275° gave a catalyst with still a very low activity. The complete removal of oxygen at 400° evidently caused a marked alternation of the nickel, and when the catalyst in this condition does catalyse the hydrogenation of ethylene it does so by a mechanism quite different from the normal mechanism already described.

Experiment 11.

The object of this experiment was to determine whether nickel oxide, partially reduced at 275°, can be made to react with ethylene in the absence of free hydrogen at any temperature up to 400°.

The catalyst was prepared as in experiment 10, hydrogen being passed for one hour at 275°. After cooling and displacing the hydrogen with nitrogen, ethylene was passed back and forth at gradually increasing temperature of catalyst up to 400°. Gas analysis showed that both ethane and hydrogen were formed. Thus, ethylene can be made to react with the catalyser in the absence of free hydrogen, but the action is abnormal, involving not only the hydrogenation of ethylene but the liberation of free hydrogen.

Experiment 12.

Sabatier and Senderens (10), and also Kelber (11), having observed that access of air to the catalyser diminishes or inhibits its activity it was deisrable to determine the extent to which oxygen is taken up by a normal catalyser at various temperatures. A catalyst was prepared by reducing three grams of nickel oxide on asbestos at

275° with hydrogen for one hour. 60 c.c. hydrogen was taken up in excess of the water formed. After sweeping out with nitrogen a measured amount of oxygen was passed back and forth at temperatures from 20° to 300°. No perceptible action occurred until about 300°.

The nickel oxide just obtained was reduced for one hour at 275°, the hydrogen displaced by nitrogen and the catalyst was then treated with oxygen for one hour at 150°C. Only a very small amount of oxygen was taken up. The free oxygen was expelled by nitrogen and a mixture of ethylene and hydrogen now passed at 150°C. During the first fifteen minutes nothing seemed to occur. However, upon letting the mixture stand for one-half hour at 150° in contact with the catalyst and then passing the gases back and forth reaction was found to proceed rapidly. It thus seems that the oxygen formed a very thin protecting layer probably by action with the outer layer of hydrogens. This had to be removed by hydrogen before the activity of the catalyst was restored. That this arrangement of hydrogens and hydroxyls is many layers thick is indicated by at least two considerations: (1) only a very small amount of oxygen is necessary to temporarily inhibit the activity of the normal catalyst, and (2) the amount of hydrogen and hydroxyl held in the surface particles is very considerable as shown by the above measurements.

Experiment 13.

It immediately became of interest to observe the nature of the reaction when a mixture of hydrogen and oxygen is passed over the active catalyst, under conditions where, in the reaction, the reduction of unchanged nickel oxide was small, not only because of this temporary inactivation of the catalyst by oxygen, but also in view of the possible light it might throw on the correctness of the views regarding the nature of the surface film and the general mechanism of this catalysis, advanced in this paper.

The catalyst was prepared by reducing nickel oxide for one hour. After displacing the hydrogen in the apparatus by nitrogen a mixture of 165 c.c. hydrogen and 180 c.c. oxygen was passed back and forth. Reaction occurred at 240-260°C. When the reduction in volume amounted to 200 c.c. the experiment was stopped and the residual gas analysed.

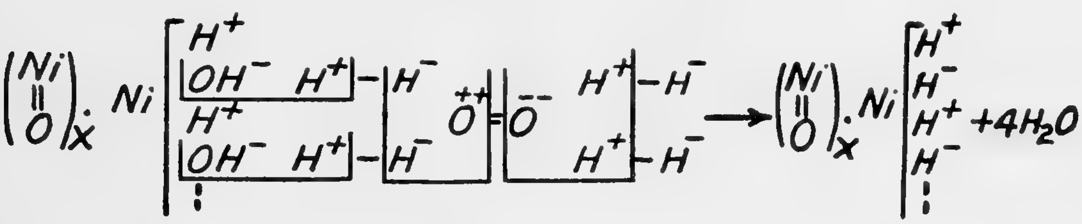
Hydrogen at start	165 c.c.
Oxygen at start	180 c.c.
	345 c.c.

Volume at end	145 c.c.
Reduction in volume	200 c.c.
Oxygen in residual gas	140 c.c.
Hydrogen in residual gas	5 c.c.
Water evolved	.0956 g.

∴ 40 c.c. oxygen and 160 c.c. hydrogen disappeared.

Now 40 c.c. of oxygen require 80 c.c. hydrogen for combination, giving .060 g. water. Therefore, 80 c.c. hydrogen disappeared in excess of the hydrogen required to combine with the oxygen which disappeared.

The interpretation of these results by means of the mechanism here advanced is not strained and seems convincing:



According to this, 4 volumes of hydrogen are represented as disappearing for every one volume of oxygen. Actually 160 c.c. hydrogen and 40 c.c. oxygen disappeared in the experiment. The amount of water required by the above equation for a disappearance of 160 c.c. hydrogen at 22°C. and 760 mm. is .1190 g., whereas only .0956 g. were evolved. That is, .0234 g. water was held on the catalyser probably mechanically.

That there was now little oxygen in the form of hydroxyl on the surface of the particles was shown by the fact that upon now passing a mixture of ethylene and hydrogen at 150° over the catalyst for one hour no hydrogenation of ethylene occurred. Upon raising the temperature to 275 water was evolved and hydrogenation of ethylene occurred. That is, before combination of hydrogen and ethylene could be catalysed it was necessary for the hydrogen on the surface of the particles to diffuse into the interior of the particles and there reduce more unchanged nickel oxide.

The use of the conception of dissociated hydrogen into positive and negative hydrogens is not new. It has been employed by physical investigators for some time. Its first use by chemists has been more recent. Lewis (12) has expressed the opinion that the mechanism of hydrogenation by nickel involves the dissociation of hydrogen followed by collisions of the substance to be hydrogenated with the metal surface carrying this dissociated hydrogen. However, Lewis does not consider the very important part which oxygen plays in this catalyst of hydrogenation. As we have seen, a nickel catalyst carrying only dissociated hydrogen and no oxygen has a very low activity, and that the normal nickel catalyser always carries a relatively large amount of oxygen. Also, Langmuir (13) has shown that a highly heated tungsten wire will dissociate hydrogen at low pressure and this hydrogen can be made to condense on a glass surface cooled by liquid air. When the wire is allowed to cool and the glass is allowed to warm to room temperature hydrogen is set free. On again cooling the glass without heating the wire the hydrogen does not condense. Also, Langmuir found that, on repeating the experiment and pumping out the free hydrogen, hydrogen still being on the glass, and now admitting oxygen, that the hydrogen on the glass combined with the oxygen, thus indicating a very active hydrogen. These effects, which Langmuir ascribes to dissociation, are more marked with platinum and palladium than with tungsten. Also, Klemenc (14) has calculated the equilibrium constant for the reaction $H^{+}+H^{-} \rightleftarrows H_2$, and has calculated the energy difference between a hydrogen atom and hydrogen carrying a negative charge. Still more recently, Hughes (15) has secured evidence which shows that dissociation can occur by a single impact of an electron with a hydrogen molecule.

This conception of negative hydrogen is directly connected with the electronic conception of valence, and the interpretation of chemical reactions in general by means of the electron theory.

In the mechanism of catalysis which is here advanced this electronic conception is applied to the experimental data.

It follows from the experimental data that the absorptive capacity of nickel for hydrogen depends on the method of preparation. If prepared from oxide by reduction with hydrogen at temperatures below 275° it would probably require many months to completely remove all the oxygen. And as we have seen the capacity of a nickel catalyst to hold hydrogen depends largely on its oxygen content. By continuous reduction at 275° for only ten hours a condition is reached where the water evolved in half an hour is relatively very small. Should this be taken as an indication of the attainment of complete reduction an utterly erroneous result would be obtained for the hydrogen adsorption capacity of nickel, for the catalyst would still contain a large percentage of oxygen. This probably explains the widely varying statements in the literature regarding the amount of hydrogen which nickel can adsorb, varying from 0.2 vols. of hydrogen per volume of nickel to a capacity for hydrogen as great as that possessed by cocoanut charcoal.

No meaning attaches to the measurement of hydrogen adsorption by nickel unless the whole history of the nickel is also described in detail. The term, it seems, should be restricted to the amount of hydrogen taken up by a known weight of nickel spread over a definite surface, the nickel having been prepared by the reduction of nickel oxide by hydrogen at a definite temperature until all the oxygen has been removed.

As nickel oxide has an indefinite composition, being always a mixture of oxides, the completion of reduction by hydrogen cannot be determined by continuing the reduction until the water equivalent of the oxygen in the oxide has been evolved. There appears to be two ways of determining whether reduction has been complete or not: (1) to continue the reduction in hydrogen until no water is evolved even after allowing the nickel to stand in the cold in an atmosphere of hydrogen for several hours and subsequently heating in a current of hydrogen, and (2) completely reduce at 400°C. and then oxidize with a known volume of oxygen at 400° and reduce at the desired temperature until the water equivalent of the oxygen adsorbed has been evolved.

From the standpoint of catalysis of hydrogenation, however, the measurement of hydrogen adsorption is, as we have just seen, of little importance, as the normal nickel catalyst is never in the condition of holding hydrogen alone.

Willstätter (9) has also pointed out that a nickel catalyst freed from oxygen by reduction at 400°C. has a very low action for catalysing hydrogenation. He produced his oxygen free nickel by the reduction by nickel oxide at 400° for six hours. Now our experiments have shown that a nickel oxide distributed in an extremely fine layer over asbestos still holds considerable oxygen after six hours' reduction at 400°. The nickel of Willstätter, we believe, still contained oxygen. However, it was probably buried in the interior of the particles, so that the action of the adsorbed surface hydrogen on this oxygen was extremely slow and as a consequence, as far as the surface was concerned, the catalyst acted as though it had lost all of its oxygen and held only hydrogen adsorbed.

Notwithstanding the relatively large amount of hydrogen adsorbed on a nickel catalyst prepared by partial reduction at 275 ethylene alone, in the absence of free hydrogen, does not react at 150°C. For hydrogenation free hydrogen must also be present. This is also true for nickel prepared by complete reduction at 400°. That is, the hydrogens on the nickel catalyst in either of the two states, (1) positive hydrogens and negative hydroxyls and (2) positive hydrogens and negative hydrogens, do not react with ethylene at 150° in the absence of free hydrogen.

According to the mechanism of hydrogenation by nickel just described most of the conflicting views of investigators are, we believe, explained. The conception of definite hydrides as intermediate products in hydrogenating actions is not valid as the normal catalyst always contains oxygen and functions, as catalyst for hydrogenations, chiefly through the hydroxyl groups on the surface. Even where the catalyst carries only hydrogen this can not be said to exist in the form of definite compounds called hydrides of definite proportion of hydrogen to nickel, but rather as complexes in which nickel carries the hydrogen adsorbed on the surface as positive and negative hydrogens.

Likewise the oxygen present in the normal catalyst is not there as a definite hydroxide of nickel, but as a complex carrying hydroxyl groups negatively charged along with hydrogens positively charged. However, although these combinations are "complexes" rather than compounds yet the hydrogens and hydroxyls react, it would appear, in stoichiometric proportions.

A great deal of additional support for the mechanism here presented comes from the satisfactory interpretation which its expansions seem to furnish for the facts known regarding phenomena at the electrodes in electrolytic cells, of over voltage, of matter in the colloidal state, of the phenomena of precipitation of colloids and adsorption of electrolytes on precipitated colloids. The state of platinum, for instance, when in solution as a sol in water is, probably, very closely connected with its state when active as a catalyser. That is, a similar relationship of hydrogen and hydroxyl to platinum exists in the two states. This theory has been further extended to express the relationship of solvent to solute in the case of true solution. In other words a similar relationship is believed to exist between solute and solvent in true solution, between dispersed substance and dispersion medium in colloidal solution and between macroscopic particles acting as catalysts and the surface water film.

These expansions of the theory will be considered in later papers.

Summary

A quantitative study of the reduction of nickel oxide by hydrogen, as well as of the catalysis of the hydrogenation of ethylene by partially reduced nickel oxide, indicates that the oxygen necessarily present in a normal nickel catalyser is present in two conditions (1) as un-

changed nickel oxide in the interior of the particles, and (2) as negative hydroxyl groups accompanied by positive hydrogens on the surface nickel of the particles. Adsorbed hydrogen is represented as positive and negative hydrogens, whose formation on the nickel surfaces is pictured as occurring in two ways. The mechanism of catalysis of hydrogenation by means of a normal nickel catalyser is represented by four reactions shown under experiment 7.

The experimental work of this paper was performed by R. C. Cantels, research assistant.

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The Constitution of Rubber

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Among the well-known carbon compounds, whose constitutions still remain to be determined, is rubber. The literature is not wanting in structural formulas, each of which represents satisfactorily one or more of the chemical reactions of rubber. However none of these is an adequate picture of all the facts which are now known regarding rubber, and the general feeling among organic chemists to-day, even among those who themselves have contributed most to our knowledge of rubber, and advanced constitutional formulas to represent it, is that the rubber molecule is much more complex than pictured by any of the constitutional formulas yet devised.

That rubber chemistry should be in this unsatisfactory condition, notwithstanding that sixty-two years have elapsed since Williams in 1860 first investigated the products of the destructive distillation of rubber, may occasion some surprise among those chemists who have not had laboratory experience in the preparation of rubber derivatives. However, it is not at all surprising to any one who has tried to isolate any of the exceedingly fragile and sensitive compounds in the pure state, from the unpromising looking sticky messes, which often result from rubber reactions. None of these compounds is crystalline, and the only method of isolation and purification available is successive solution and precipitation, using as many different solvents and precipitants as are applicable. This has been the chief difficulty. However, an equally important reason for the delay in arriving at a satisfactory representation of the constitution lies, in my opinion, in the unfortunate choice of reactions which have been used for constitution determination. The reactions are altogether too drastic and carry the process of depolymerization of the rubber molecule so far that the final products bear, in most instances, no simple relationship to the original rubber, and have led to the opinion that the rubber molecule is much simpler than it really is. Such reactions as bromination, action of ozone, and of hydrochloric acid gas on rubber, the removal of chlorine from the product of the action of hydrochloric acid gas by heating with pyridine under pressure and others are, though they have given valuable information, too deep seated to enable final inferences to be drawn regarding constitution.

The object of this paper is very briefly to review the facts regarding rubber, which have given rise to the formulas already suggested, and to describe some new rubber reactions and new rubber compounds which substantiate, in a measure, a new constitutional formula which appears not only to be in harmony with the new facts, but also adequately to express the older ones. The chief virtue of these new rubber derivatives, which we have made, for constitutional purposes, lies in the fact that in the reactions used in producing them, the rubber molecule was only very slightly altered, in some cases the depolymerization of the main nucleus of carbon atoms not having occurred, I believe, at all. Evidently such reactions should throw considerable light upon the extent of the rubber molecule, and, in conjunction with those reactions involving a partial splitting off of groups from this nucleus, should enable the derivation of a satisfactory structural formula to be attempted.

Review of Literature

There is no occasion here to review exhaustively the literature. This has already recently been done by others, notably by Harries in Liebigs Annalen der Chemie, and in his Untersuchungen über Kautschukarten. I shall accordingly review the reactions only in sufficient detail to make clear their bearing upon the problem of constitution.

The products formed by the destructive distillation of rubber were investigated by Williams (1), Wallach (2), Bouchardat (3), Fischer (4), Harries (5) and others. Among the products isoprene and dipentene were identified. The importance of isoprene was emphasized by the discovery by Bouchardat (6) and by Tilden (7) that this hydrocarbon could be polymerized by dilute hydrochloric acid and by long standing to form rubber like masses.

Tilden (8) had proposed the formula $CH_2=\overset{\displaystyle CH_3 \atop |}{C}-CH=CH_2$ for isoprene, and this constitution was verified by Ipatiew and Wittorf (9). Ipatiew (10) also showed the so-called isoprene fraction, obtained on distilling rubber, to be a mixture chiefly of isoprene and trimethylethylene.

More recently a number of syntheses of isoprene have been developed both in England and Germany, many of them covered by patents. Also much work has been carried out, notably by Harries (11) at Kiel, and by Perkin, Matthew and Strange (12) in London upon the polymerization of isoprene to rubber by means of acetic acid and metallic sodium.

Thus rubber came to be looked upon as a polymerization product of isoprene $(C_5H_8)_x$, especially after Gladstone and Hibbert showed that rubber does in reality possess the empirical formula C_5H_8. It may be mentioned in passing that these polymerizations products of isoprene are somewhat closely related chemically to rubber, but are not identical with it.

Commercial rubbers were also known to contain varying amounts of acetone soluble compounds called resins. These were found to be oxygen containing compounds, and led to the investigation by Herbst (13) and others of the action of free oxygen on a benzol solution of rubber. Herbst definitely isolated a compound of the empirical formula $C_{10}H_{16}0$. I shall return to the consideration of these compounds presently, in connection with the products of the oxidation of rubber by hydrogen peroxide, by potassium permanganate and by free oxygen, obtained in this laboratory. I only wish, at this point, to indicate that this $C_{10}H_{16}0$ compound was among the first prepared of those derivatives of rubber indicating the existence of $C_{10}H_{16}$ in the rubber molecule.

We thus see how the two ideas which have dominated rubber chemistry have arisen, viz.: (1) that rubber is a polymerization product of isoprene and (2) that the rubber molecule consists of several $C_{10}H_{16}$ groups in combination.

The action of halogens upon rubber was studied by Gladstone and Hibbert (14). On passing chlorine through a chloroform solution of rubber they obtained a compound, the analyses of which left them undecided between the formulas $C_{10}H_{14}Cl_8$ and $C_{10}H_{12}Cl_8$. Hydrochloric acid was evolved in the reaction, indicating substitution of hydrogen by chlorine, although the major part of the reaction was one of direct addition of chlorine. Using bromine in place of chlorine they obtained as chief product a mixture of compounds of the composition $C_{10}H_{16}Br_4$. Weber stated that the so-called tetrabromide of rubber, after precipitation and washing, had a constant composition. Budde (15) developed an analytical method for the determination of rubber in mixtures based upon this reaction.

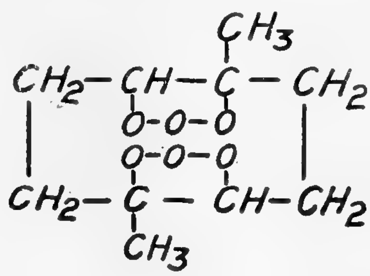
The reaction of hydrochloric acid upon a benzol solution of rubber was studied by Weber (16). He isolated a product having the composition $C_{10}H_{16}2HCl$. Harries and Fonrobert (17) confirmed this observation and also found that upon repeated washings and precipitations the halogen content decreased considerably. Weber found that upon gentle warming the chlorine content fell from 32% to 18%. Harries found that this could be still further decreased to 12.3% on warming to 100° in vacuo and on heating with pyridine under pressure. That is, the chlorine content fell to below that corresponding to the formula $C_{10}H_{16}HCl$. This was one of the observations which led Harries to an expression of a marked loss of confidence in a $C_{10}H_{16}$ formula of rubber which he had advocated for many years. I will consider this formula presently.

At this stage of the development of rubber chemistry this action of halogens and of halogen acids was accepted as proof that the rubber molecule, consisting of $C_{10}H_{16}$ groups associated together, is unsaturated, each $C_{10}H_{16}$ containing two pairs of unsaturated carbon atoms.

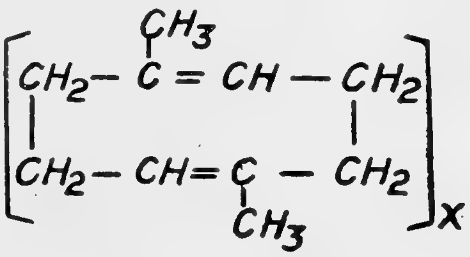
Other work had also been performed on iodine derivatives and upon the action of nitrogen tri-oxide upon rubber yielding the so-called nitrosites. However, these did not contribute anything to the problem of constitution.

This, briefly, was the condition of this problem prior to the year 1910. During this year Lebedew (18) published a paper upon the products of the action of ozone upon some diethylenic hydrocarbons and the products of these so-called ozonides upon decomposition with steam. This work, which was substantiated and expanded greatly by Harries (19), threw a flood of light upon the constitution of rubber. Briefly, it was found that diethylenic compounds when acted upon by ozone add on three atoms of oxygen at each double bond, and the subsequent decomposition of these ozonides yield aldehydes and acids related in a very clear way with the original diethylenic compounds, so that by preparing the ozonides in the case of similar compounds and isolating the products upon hydrolysis it should be possible to derive their constitutions.

This was done by Lebedew and Harries. It was found that the product obtained when a chloroform solution of rubber is treated with ozone, formed, when decomposed by steam, laevulinic aldehyde, laevulinic aldehyde peroxide and laevulinic acid. These investigators concluded that rubber diozonide has the constitution:

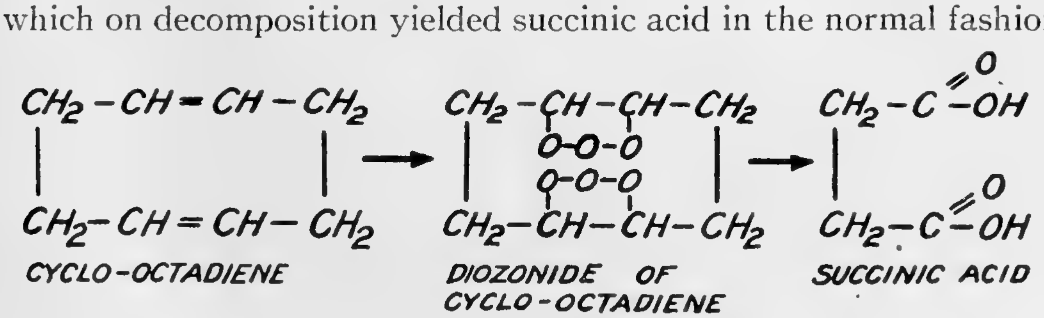


which should decompose in a manner similar to the ozonides of other diethylenic compounds. Accordingly rubber would have the constitution of polymerized symmetrical dimethyl cyclo octadiene:



Until quite recently Harries has been an ardent advocate of this constitution. Indeed, it does appear, as Harries has pointed out, to represent many of the conclusions just referred to. It consists of $C_{10}H_{16}$ groups linked together, each $C_{10}H_{16}$ containing two double bonds, which is, as we have seen, in harmony with the conclusions arrived at by investigators up to that time, and it is apparently in harmony with the formation of a diozonide yielding upon decomposition, laevulinic aldehyde and acid. Harries also maintained that it satisfactorily represents the formation of isoprene and dipentene, upon distillation of rubber. It will be observed that in the formation of isoprene the molecule is represented as breaking at two single bonds and not at the double bonds, which are the usual points of weakness. Also in the formation of dipentene a marked intermolecular displacement must be assumed, unless the dipentene has been produced, by polymerization of isoprene first formed in the distillation.

Harries also maintained that still further support for this constitutional formula for rubber was obtained from the fact that the synthetic rubber obtained by him by the polymerization of butadiene was identical with a hydrocarbon which Willstätter had prepared from a naturally occurring alkaloid pseudo-pelletierin, and which Harries showed to have the constitution cyclo octadiene. This synthetic rubber and this hydrocarbon gave a diozonide $C_8H_{12}O_6$ which on decomposition yielded succinic acid in the normal fashion.



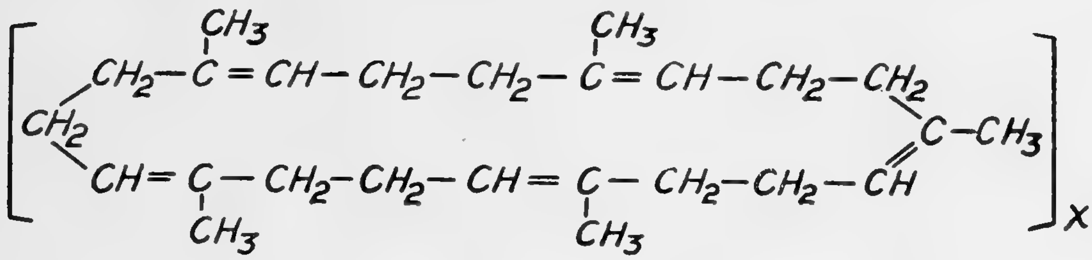
If now, Harries continued, methyl butadiene (isoprene) polymerizes to form a synthetic rubber, after the same plan, it should produce dimethyl cyclo octadiene of the constitution already given, whose ozonide upon decomposition should yield laevulinic acid and aldehyde. However, acetonyl acetone and succinic acid were obtained instead. This, however, is easily understood if the polymerization of isoprene yielded unsymmetrical dimethyl cyclo octadiene instead of the symmetrical compound. So that the synthetic rubber from isoprene has the unsymmetrical constitution, and the fact that acetonyl acetone and succinic acid are formed from the diozonide instead of laevulinic aldehyde constitutes no objection to the main contention of Harries.

Pickles raised the objection that, according to the Harries constitution, "the vague and unnecessary conception of polymerization" is employed, and suggested that the rubber molecule consists of isoprene groups linked up successively in one large ring, thus:

$$-CH_2.\underset{\underset{CH_3}{|}}{C}-CH-CH_2-CH_2-\underset{\underset{CH_3}{|}}{C}-CH-CH_2-CH_2-\underset{\underset{CH_3}{|}}{C}-CH-CH_2-$$

the ends of the chain being connected so as to constitute a large ring not further polymerized. He further suggested that the various rubbers differ in the number of such nuclei in the ring. That is, Pickles places all the isoprenes in the whole rubber molecule in one huge ring, this molecule not being subsequently polymerized.

It was about this time that Harries became suspicious of the polymerized dimethyl cyclo octadiene constitution, having, among other observations, found that the chlorine content of the hydrochloric acid addition product of rubber, $C_{10}H_{10}$ 2 HCl, could be made to fall below $C_{10}H_{16}$ HCl, on heating with pyridine under pressure. It would appear that Harries was scarcely justified in abandoning his constitution on these grounds, for the actions seem altogether too drastic to warrant drawing any definite conclusions at all regarding the constitution of the original rubber molecule. However, he set up a constitution very similar to Pickles, in that five molecules of isoprene are linked together in a single ring. But he adhered to the notion that this large ring must itself be polymerized to a compound of much higher molecular weight $(C_{25}H_{40})_x$. His objection to having all the isoprenes in one ring without further polymerization was that such a compound would not likely depolymerize easily, while it was known that rubber undergoes a change (which Harries called depolymerization) when worked mechanically on hot rolls.



New Views Regarding the Constitution

In 1917 work commenced on the constitution of rubber in the School of Engineering Research of the University of Toronto. A study of the literature led me to the conclusion that the dimethyl cyclo octadiene constitution of Harries is unsatisfactory for the following reasons:

(1) The formation of two mols of isoprene from one mol of dimethyl cyclo octadiene requires a severing of two single bonds in a molecule containing two double bonds. Double bonds between carbons are usually points of weakness in a molecule and consequently rupture when it occurs usually takes place there rather than between carbons formed by a single bond. This had been pointed out by Pickles.

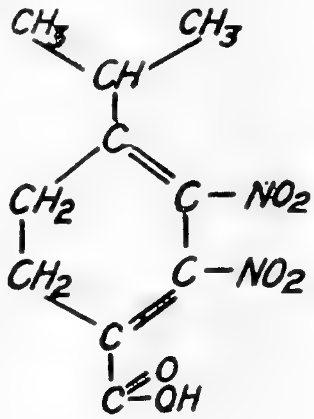
(2) The formation of dipentene from dimethyl cyclo octadiene entails a very extensive intermolecular change, the mechanism of which is not clear unless the intermediate formation of molecules of isoprene is assumed with subsequent polymerization to dipentene.

Were dipentene and isoprene actually linked up as constituents of the rubber molecule both of these objections would be removed.

(3) With double bonds existing in the rubber molecule it should be possible to add hydrogen directly and produce a saturated hydrocarbon. The endeavours of Harries (20) and of Hinrichsen (21) and Kempf to accomplish this failed. Likewise all attempts made in this laboratory were unsuccessful. This would seem to indicate that rubber contains no ethylene linkages at all. Belief in the unsaturated character of rubber depends on the observations that rubber adds on approximately four bromines and two hydrochloric acid mols for each $C_{10}H_{16}$. However, as these are admittedly very drastic actions, almost certainly accompanied by deep seated depolymerization of the rubber molecule, it is conceivable that the rubber mol itself contains no double bonds whatever, and that these are only produced by the breaking up of the complex rubber molecule by the action of bromine

or hydrochloric acid. That bromine and hydrochloric acid add to a polymerized compound like rubber constitutes no proof that ethylene linkages are present in the original rubber molecule.

(4) Ditmar (22) has produced a dinitro compound by the action of nitric acid in rubber. This was verified by Harries. Ditmar has shown that this compound is a dinitro cumic acid of the constitution



This contains a six membered ring and closely resembles dipentene. Its formation from a molecule containing dipentene as a constituent part could be easily understood. Its formation from a mol containing only dimethyl cyclo octadiene is not capable of any easy explanation.

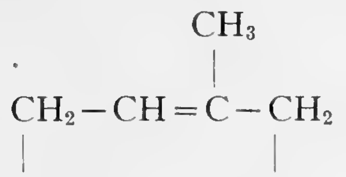
(5) The synthetic rubbers made by Harries from butadiene, methyl butadiene (isoprene) and dimethyl butadiene by polymerization with metallic sodium, and which Harries believes possess the cyclo octadiene structure, are much more easily oxidized than natural occurring rubber. These synthetic rubbers possibly consist solely of octadiene constituents and as a consequence contain ethylene linkages which thus render these synthetic rubbers more susceptible to the action of oxygen, the greater stability of the natural rubber being due to the absence of such unsaturated bonds.

A New Constitution for Rubber.

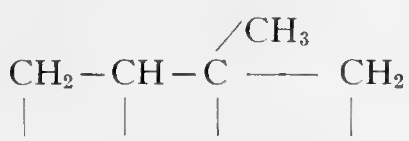
For these reasons a provisional working hypothesis was set up that the rubber molecule contains within it a dimethyl cyclo octadiene part, a dipentene part and an isoprene part.

The various probable methods of polymerization of isoprene were then examined. It is obvious that isoprene can polymerize in two ways:

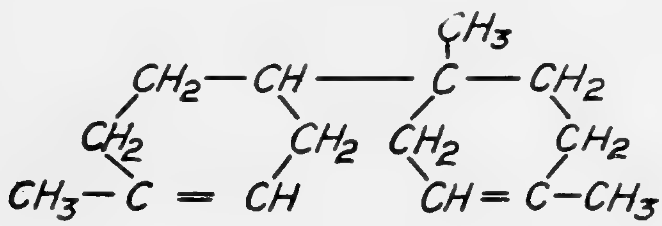
(1) By means of the free bonds, thus



and (2) by means of the free bonds, thus

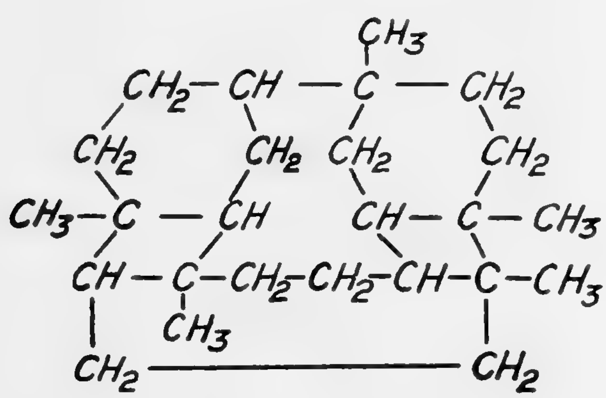


Obviously one mode of polymerization consists of a union of one mol of isoprene exercising the free bonds represented in (2) with two mols of isoprene exercising the free bonds represented in (1) to form the following:



This contains three isoprene nuclei arranged in such a way as also to contain a dipentene nucleus.

This now contains two double bonds, each of which might conceivably link up with a mol of isoprene by means of bonds as represented in (2), thus:



Many other methods of polymerization can be constructed, but upon examination the resultant constitutions do not fulfil the requirements just discussed so adequately as does, I believe, this one.

It represents a compound containing a dimethyl cyclo octadiene group, a dipentene group and an isoprene group. It contains no ethylene linkages at all. It should admit of easy depolymerization in a variety of ways. Thus it should give rise to derivatives of

C_5H_8,$C_{10}H_{16}$, $C_{15}H_{24}$, $C_{20}H_{30}$ and $C_{25}H_{40}$. It will be shown presently that this is in reality so. We have made oxygen derivatives of such molecules from rubber by means of free oxygen, by hydrogen peroxide and by potassium permanganate. Upon action with bromine, no matter in what manner depolymerization should occur, the final product should have the percentage composition $C_5H_8Br_2$ or $C_{10}H_{16}Br_4$. Likewise, the hydrochloric acid addition product should have the composition C_5H_8HCl or $C_{10}H_{16}.2\ HCl$. It explains the ready formation of dipentene from rubber and the production of dinitro cumic acid, so closely related to dipentene, observed by Ditmar.

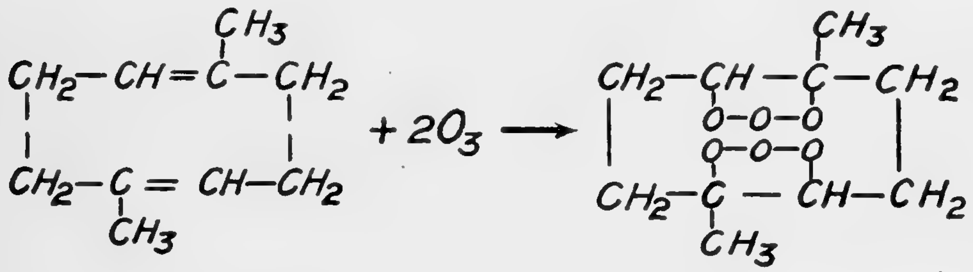
An apparent objection is found in the action of ozone on rubber. At first sight it would seem that since the sole products of the decomposition of the ozonide of rubber, as Harries claims, are laevulinic aldehyde, laevulinic aldehyde peroxide and laevulinic acid, that the possibility of the presence of any group other than dimethyl cyclo octadiene is excluded. Upon closer examination, however, this objection does not seem to be valid. Harries prepared the diozonide of rubber by the action of ozone upon a chloroform solution of rubber. This ozonide was precipitated from solution and washed. The possibility is not excluded, that in the preparation of this ozonide in the pure state, other oxygen products of the action were removed. Unless I have overlooked the statement I can find no mention of a quantitative yield of $C_{10}H_{16}0_6$ having been obtained from a known weight of rubber. What appears to have been obtained was a quantitative yield of the products of decomposition of the purified diozonide. Dingman, in this laboratory, endeavoured to determine quantitatively the yield of diozonide obtainable from a known weight of rubber made by Harries method, drawing off the adhering solvent and precipitant in a vacuum at room temperature. However, he was unable to get constant weight, as the diozonide decomposed under these conditions, and so no decision could be reached.

Since writing this my attention has been drawn to a paper by Olivier (22) in which he has obtained the same result, viz., impossibility to obtain constant weight of diozonide. Moreover, Olivier found that he could obtain no constancy of the molecular weight of the so-called diozonide by the freezing point method using benzene as solvent. The values varied from 558 to 869 for moderate treatment with ozone and from 321 to 487 for the product purified after excessive treatment with ozone. Olivier comes to the same conclusion that there is no proof that Harries diozonide is a homogeneous compound. And unless this diozonide of the constitution given is the sole product of the action of ozone then Harries constitution is not valid.

Olivier expresses the belief that in spite of the detailed researches of Harries not much progress has been made in the determination of the constitution of rubber.

However, even supposing the transformation of rubber into $C_{10}H_{16}O_6$ does occur quantitatively, this would not constitute a decisive objection to the above formula.

For the action of ozone is of an exceedingly violent sort and must result primarily in a very thorough depolymerization of the whole rubber molecule. It is not inconceivable that the five resulting isoprene residues might rearrange themselves to form a diozonide of dimethyl cyclo octadiene. Each pair of isoprene residues might recombine to form the single diozonide thus:



Experimental.

However probable this constitution which I have devised may appear, from the facts which I have just briefly reviewed, more conclusive evidence is desirable indicating the existence of a $C_{25}H_{40}$ nucleus in the rubber molecule. The experiments which have been carried out by my students (A. Hambleton, R. R. McLaughlin and R. R. Parker) were performed in an endeavour to prepare derivatives of rubber by the mildest kind of action, in order to avoid as much as possible the depolymerization of the rubber molecule. Oxidations by means of a water solution of potassium permanganate, a water solution of hydrogen peroxide, oxygen of the air, the action of iodine and of iodine with hydrogen peroxide were employed.

Oxidation by Potassium Permanganate—Experimental Work by A. Hambleton.

The rubber for these experiments was prepared by extracting about 200 g. of para rubber, cut up into small pieces, with hot acetone. The acetone was poured off frequently and fresh acetone added. This was continued for eight days, when the extract was found to leave no residue or evaporation. The excess of acetone sticking to the rubber was evaporated on a water bath, the rubber dissolved in carbon tetra chloride and filtered through glass wool, and the solution poured slowly with stirring into approximately twice its volume of methyl alcohol. The rubber precipitated as a white gummy mass. This was warmed in a steam oven for an hour to drive off the excess of solvents and the remainder drawn off under suction.

7½ grams of rubber dissolved in 150 c.c. carbon tetrachloride, 11.62 g. powdered potassium permanganate, and 150 c.c. water were placed in a 500 c.c. glass stoppered bottle and shaken for five days at room temperature. At the end of this time the permanganate colour had disappeared. The contents of the bottle was then filtered on a large Büchner funnel. The water and carbon tetrachloride in the filtrate was separated in a separating funnel. The carbon tetrachloride solution was concentrated to half its bulk under suction and at a temperature not exceeding 45°.

The clear colourless solution was poured into twice its volume of pure methyl alcohol in an erlenmeyer flask. Here it was washed by decantation with acetone, ethyl alcohol and methyl alcohol. The white pasty mass was then freed from solvent by a high vacuum in the cold. Samples of this were analysed, giving the following results:

Analyses (1)

Substance	H_20	$C0_2$	%C	%H	%0
.1764 g.	.1808	.5405	83.7	11.4	4.9
.1511	.1538	.4653	84.1	11.3	4.6
.1386	.1427	.4283	84.4	11.4	4.2

Although the greatest care was taken to exclude free oxygen in the drying of this product and in removing the last traces of solvent, yet for certainty the preparation and purification was carried out twice again. The additional precaution was taken of dissolving the preparation finally in petroleum ether (B.P. 31-42) and evaporating the solvent in a high vacuum in the cold, in this way assisting in the removal of any traces of methyl alcohol which was the washing liquid used just prior to solution in the petroleum ether. This solution in petroleum ether and evaporation was repeated. In this way it was reasonably certain that every trace of oxygen holding solvent was removed. In the second repetition this was also done, using benzol instead of petroleum ether. This was the more necessary as Harries (23) and also van Rossem (24) studied the action of potassium permanganate on rubber and were unable to isolate any oxidation product related to rubber. Following are the results of analyses:

Analyses (2). Using Benzol.

Substance	H_20	$C0_2$	%C	%H	%0
.1244	.1316	.3832	84.1	11.7	4.2
.1764	.1808	.5405	83.7	11.4	5.9

Analyses (3). Using Petroleum Ether

Substance	H_20	$C0_2$	%C	%H	%0
.2000	.2076	.6125	83.5	11.5	5.0
.1734	.1751	.5290	83.7	11.2	5.1

Collecting the analyses and comparing with the calculated values for $C_{25}H_{40}0$.

	C	H	0
Found	83.7	11.4	4.9
	84.1	11.3	4.6
	84.4	11.4	4.2
	84.1	11.7	4.2
	83.7	11.4	5.9
	83.5	11.5	5.0
	83.7	11.2	5.1
Average of Found Values	83.9	11.4	4.8
Calculated	84.3	11.2	4.5

There seems to be no doubt that an oxygen compound of the composition $C_{25}H_{40}0$ has been prepared.

This compound readily takes up oxygen on warming slightly in the air or even on standing in the air for a short time at room temperature. Upon analysis of two different preparations the following results were obtained:

Substance	H_2O	CO_2	%C	%H	%O
.1903	.1906	.5574	81.2	11.1	7.7
.2031	.2016	.6081	81.7	11.0	7.3
.1935	.1925	.5733	80.8	11.1	8.1
Average			81.2	11.1	7.7
Calculated for $C_{25}H_{40}O_2$			80.65	10.75	8.6

This latter compound was prepared in a purer condition from the reaction product of hydrogen peroxide on rubber, according to details described later in this paper.

The freshly precipitated $C_{25}H_{40}O$ compound is easily soluble in ether, petroleum ether, carbon tetrachloride, chloroform, benzol, carbon bisulphide and insoluble in ethyl alcohol, methyl alcohol and acetone.

It has a dough-like consistency. It is apparently unacted on by cold acids and bases and rapidly takes up oxygen from the air when warmed and more slowly at room temperature, combining with one atom of oxygen for every mol of $C_{25}H_{40}O$.

Action of Hydrogen Peroxide—Experimental Work by R. R. Parker and R. R. McLaughlin.

5 g. rubber dissolved in 125 c.c. carbon tetrachloride and 125 c.c. of a 3% hydrogen peroxide solution were placed in a glass stoppered bottle and shaken for one week at room temperature. The whole was allowed to stand twenty-four hours and then filtered when only a small residue remained. The water and carbon tetrachloride in the filtrate were separated and each evaporated at ordinary temperature under suction. The water solution evaporated to a white sticky material which, on attempting to dry to constant weight, was found to absorb oxygen rapidly, when taken out of the vacuum vessel, for weighing. This compound will be investigated later.

The residue from the evaporation of the carbon tetrachloride solution gave a transparent, bright yellow substance fairly hard, at room temperature. This was found to be mostly soluble in ether and leaving a residue insoluble in ether. The separation was made by extracting with two portions of ether for eight hours each. The combined extracts were evaporated at room temperature to about 25 c.c. and methyl alcohol added when a white gummy mass was obtained. This was filtered off and washed with methyl alcohol, ethyl alcohol and acetone and dried to constant weight at room temperature under suction. This was again partially dissolved in ether, filtered, precipitated and washed as before and dried to constant weight. The substance was now analysed, giving the following result:

Substance	H_20	$C0_2$	%C	%H	%0
.2827 g.	.2758	.8872	85.59	10.84	3.57
.2879	.2870	.9025	85.49	11.07	3.44
Average			85.54	10.96	3.50
Calculated for $C_{30}H_{48}0$			84.90	11.32	3.78

A sample of this compound, which had stood for some time in the air, was partially redissolved in ether, filtered, precipitated, washed and dried to constant weight. Analyses were as follows:

Substance	H_20	$C0_2$	%C	%H	%0
.2768	.2570	.8153	80.33	10.31	9.36
.3013	.2844	.8875	80.33	10.48	9.19
Average			80.33	10.40	9.27
Calculated for $C_{25}H_{40}0_2$			80.64	10.75	8.61

This compound appears to be identical with the $C_{25}H_{40}0_2$ compound just described as one of the products of the oxidation of the $C_{25}H_{40}0$ compound in the air.

This would indicate that a nucleus $C_{30}H_{48}$ occurs in the rubber molecule and that the first product of oxidation is $C_{30}H_{48}0$. This compound readily loses an isoprene group and becomes $C_{25}H_{40}0$. In place of this C_5H_8 group an oxygen then enters, giving the compound $C_{25}H_{40}0_2$. This is entirely in harmony with the above results. It is also verified by the fact that in the hydrogen peroxide oxidation of rubber a water soluble oxidation product, already referred to, is formed which probably results from the oxidation of this isoprene group which has been split off. Also Hambleton, in this laboratory, observed that when rubber is oxidized by potassium permanganate in the preparation of the $C_{25}H_{40}0$ compound, there is a water soluble oxidation product as well as considerable carbon dioxide formed. He measured the amount of carbon dioxide formed in the oxidation and found that about 5% of the rubber was oxidized to carbon dioxide. It seems, then, that there is an isoprene group which is readily oxidized by permanganate partly to a water soluble acid and partly to carbon dioxide. The hydrogen dioxide oxidation leaves some of this unstable $C_{30}H_{48}0$ unattacked. The probable mechanism of these changes and the constitution of the $C_{30}H_{48}$ molecule will be discussed presently in this paper.

The material insoluble in ether was dissolved in a small amount of carbon tetrachloride and precipitated by methyl alcohol, washed and dried at room temperature in a vacuum to constant weight. This was a sticky mass which had a resin like odour. There was only enough material for a single analysis.

Material	H_20	$C0_2$	%C	%H	%0
.2477	.2427	.7392	81.39	10.80	7.81
Calculated for $C_{15}H_{24}0$			81.81	10.90	7.29

On heating some of the above ether soluble compound to 100° it became partially insoluble in ether. Whether this ether insoluble part is the same as the ether insoluble compound whose analysis has just been given is not known. It will be investigated later.

Action of Oxygen of the Air on Rubber.—Experimental Work by R. R. McLaughlin and R. R. Parker.

About 300 g. of resin-free rubber was rolled out into very thin sheets and suspended in frames in direct sunlight for three months. It was then extracted with acetone for two days and the acetone extract was evaporated at room temperature. Approximately 30% of the rubber had resinified. It was found that a separation of the resin could be accomplished with carbon bisulphide. The whole of the resin was extracted at room temperature with carbon bisulphide and filtered at the pump, leaving a residue. The carbon bisulphide solution was evaporated at room temperature and the residue so obtained was dissolved in acetone, using a large amount of solvent to facilitate filtration and the whole filtered. This solution was evaporated at room temperature to a small bulk and the compound precipitated with methyl alcohol. This was filtered and dried to constant weight under suction. This gave a tough rubbery substance.

The part of the oxidation product insoluble in carbon bisulphide was shaken for twenty-four hours with carbon bisulphide to remove all the carbon bisulphide soluble and filtered. This was dissolved in acetone for the purpose of precipitating it, but the precipitate with methyl alcohol was of such a consistency that it could not be separated effectively from the solvents. The whole was evaporated at room temperature under suction and gave a hard, brittle and transparent mass.

Analysis of Compound Soluble in Carbon Bi-Sulphide.

Material	H_20	$C0_2$	%C	¾H	%0
.2482	.2278	.7141	78.47	10.15	11.38
.2956	.2760	.8532	78.72	10.37	10.91
Average			78.59	10.26	11.14
Calculated for $C_{10}H_{16}0$			78.95	10.53	10.53

Analysis of Compound Insoluble in Carbon Bi-Sulphide

Material	H_20	$C0_2$	%C	%H	%0
.3076	.2328	.6997	62.04	8.41	29.55
.2912	.2105	.6649	62.27	8.03	29.70
Average			62.16	8.22	29.62
Calculated for $C_{25}H_{40}0_9$			61.98	8.26	29.76

Action of Hydrogen Peroxide and Iodine on Rubber.—Experimental Work by R. R. McLaughlin and R. R. Parker.

5 g. rubber dissolved in 125 c.c. carbon tetrachloride, 125 c.c. of a 3% hydrogen peroxide solution, 100 c.c. of a 2% solution of iodine in carbon tetrachloride were placed in a glass stoppered bottle and shaken for two weeks at room temperature. It was allowed to stand for twenty-four hours when it separated in two layers. The whole was filtered at the pump, requiring several hours, washed with carbon tetrachloride, dried in air at temperature not above 30°C. The product was then rubbed up in a mortar and extracted with carbon tetrachloride to remove all free iodine, dried, dissolved in ethyl acetate and filtered. The residue on the filter was washed several

times with ethyl acetate and dried to constant weight. A light yellow solid was obtained.

The filtrate containing the part soluble in ethyl acetate was evaporated under suction at room temperature with the exclusion of direct sunlight, as this solution, if exposed to light and air, becomes black in colour. The solid obtained was partially redissolved in ethyl acetate, filtered and evaporated as before to constant weight. It has a varnish-like appearance and on scraping off the dish and grinding, was a brownish-yellow powder.

Analysis of Compound Soluble in Ethyl Acetate

Material	H_2O	CO_2	%C	%H	%I	%O
.2520	.1479	.4791	50.77	6.52	21.34	21.54
.2470	.1608	.4538	50.10	7.23		
.2108	.1234	.3884	50.25	6.54		
	Average		50.37	6.76		

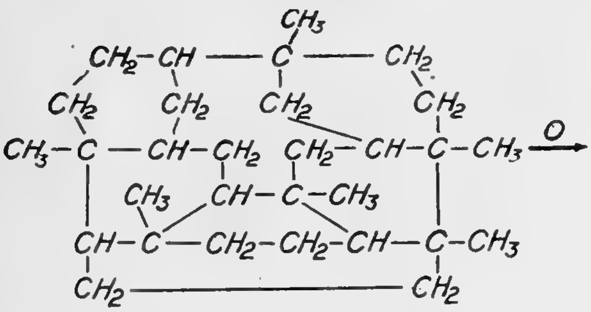
Material	Silver Iodide	%Iodine
.2500	.0990	21.34

	%C	%H	%I	%O
Calculated for $C_{25}H_{40}O_8I$	50.42	6.72	21.34	21.59
Found	50.36	6.76	21.34	21.54

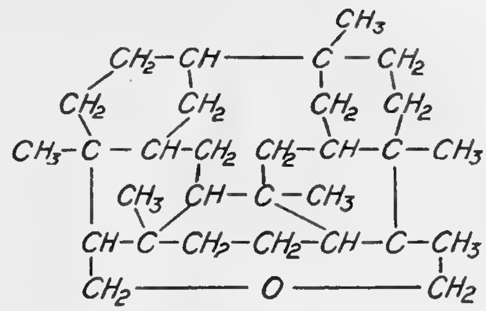
No solvent could be found for the compound insoluble in ethyl acetate and as it was obviously impure it was set aside and will be investigated later.

Interpretation of Results

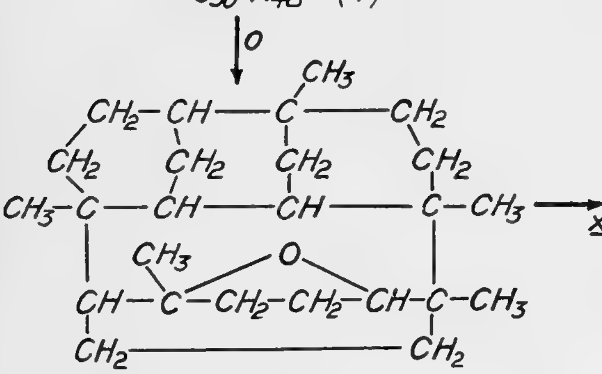
The results of the experiments just described seem to receive an adequate explanation by the following:



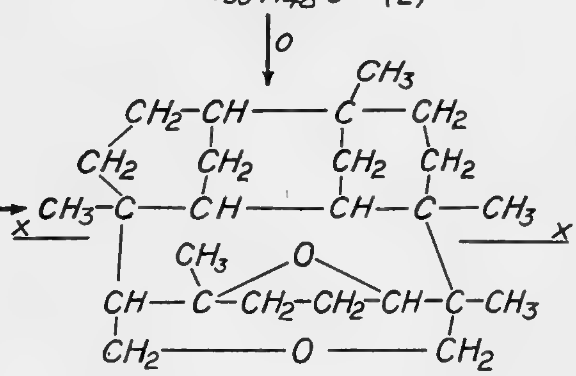
$C_{30}H_{48}$ (1)



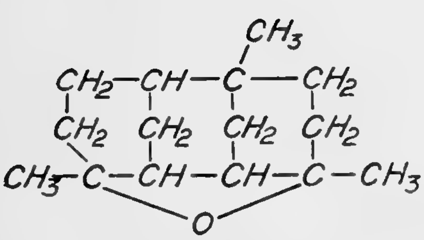
$C_{30}H_{48}O$ (2)



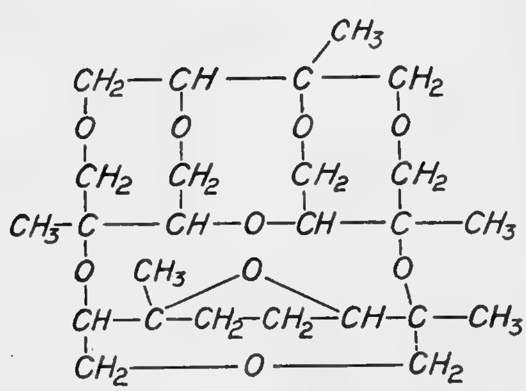
$C_{25}H_{40}O$ (4)



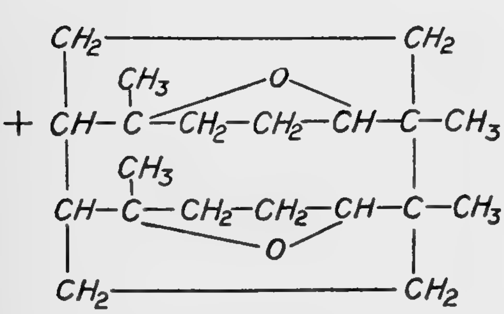
$C_{25}H_{40}O_2$ (3)
+ OXIDATION PRODUCT OF C_5H_8



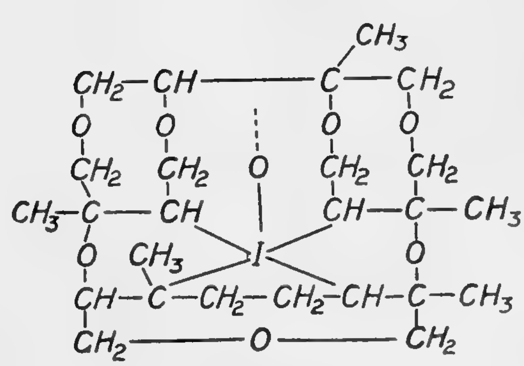
$C_{15}H_{24}O$ (5)



$C_{25}H_{40}O_9$ (7)



$C_{20}H_{32}O_2$ (6)



$C_{25}H_{40}IO_8$ (8)
$C_{50}H_{80}I_2O_{16}$

Rubber consists of six isoprene molecules polymerized to form a molecule $C_{30}H_{48}$ of the constitution shown in Fig. 1. Upon oxidation with hydrogen peroxide this is oxidized first to $C_{30}H_{48}O$, probably of the constitution shown in Fig. 2. This is the beginning of the insertion of oxygen between the isoprene groups. This compound readily loses its central C_5H_8 group, which is, as we have seen, oxidized to CO_2, and a water soluble compound, and an oxygen enters the molecule in its place, making the compound $C_{25}H_{40}O_2$ represented by Fig. 3. This compound $C_{25}H_{40}O_2$ can also be made by the oxidation of rubber by potassium permanganate. In this case the central isoprene is oxidized off to CO_2 and a water soluble compound, and $C_{25}H_{40}O$ is formed, which is represented in Fig. 4. This readily takes up oxygen and passes into $C_{25}H_{40}O_2$, represented in Fig. 3. Another product of the oxidation of rubber by hydrogen peroxide has the composition of $C_{15}H_{24}O$. This probably forms from the further oxidation of the $C_{25}H_{40}O_2$ compound, whereby the split occurs along the line $x-x$, the two free bonds uniting with an oxygen to produce $C_{15}H_{24}O$ of the constitution in Fig. 5. It is probable that another oxidation product $C_{20}H_{32}O_2$ is also formed in this reaction, of the constitution represented in Fig. 6, although this was not isolated. However, this compound was found among the oxidation products of rubber by oxygen of the air. In this oxidation of rubber by air the final product of the oxidation before the molecule disintegrates is $C_{25}H_{40}O_9$, represented by Fig. 7. Here the five isoprene groups are separated from each other by oxygens. The molecule is unable to take up more oxygen without rupture.

The action of iodine and hydrogen peroxide on rubber gives two compounds only one of which was purified and analysed. It has the composition $C_{25}H_{40}I\ O_8$. An important consideration in arriving at its constitution is the fact that iodine alone acts with very great slowness on rubber but that in the presence of oxygen it acts at once with the entrance of a single iodine and eight oxygens for every $C_{25}H_{40}$. Since the final product of oxidation of rubber by free oxygen has the composition $C_{25}H_{40}O_9$, it seems highly probable that this single iodine serves to link up the five isoprene groups in the $C_{25}H_{40}$ molecule occupying then a central position in some such way as represented in Fig. 8. This requires another oxygen in order to make up the required eight oxygens. This is represented as united to the iodine by a single bond. A second residue may possibly be united to this at the two oxygens giving the molecular formula $C_{50}H_{80}I_2O_{16}$. Only a molecular weight determination can decide whether any combination of this kind occurs. Iodine here acts with a valency of five, which is not unusual for iodine as it is found with this valency in iodic acid and iodine pentroxide.

Summary

A survey of the facts of rubber chemistry is given and a criticism of the interpretations of these facts by previous investigators presented.

A new constitutional formula for rubber is advanced, which seems more in harmony with these facts.

Some new oxygen and iodine derivatives of rubber are described which substantiate this constitution.

Provisional formulae are presented for the constitutions of these derivatives.

This work is being continued in this laboratory.

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On an Application of the Theory of Magnetism to the Calculation of Atomic Diameters

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I. *Introduction*

During the course of some advanced work on the theories of magnetism the attention of the writer was directed to the possibility that the modern conceptions of the structure of the atoms, as proposed by Bohr or by Lewis and Langmuir, might be utilized in conjunction with the theory of magnetism, developed on the basis of the electron theory by Langevin and extended by Weiss, Kunz, Honda and others, to deduce an estimate of the atomic diameters of the elements. At the same time some rather striking relations of the magnetic properties of the families of the elements as arranged in the periodic system came to light and have been briefly summarized in the first part of the paper, without attempting in too great detail to correlate them to the structure of the atoms concerned. Indeed, until the probable arrangements and motions of the electrons of the atomic systems have been more thoroughly tested both by a theoretical survey of the conditions of stability of the atomic structures proposed and, on the experimental side, by investigations of the conditions necessary for the production of the different types of spectra of the elements and the correlation of these to definite processes in the atomic system, the magnetic properties of the elements, like the chemical properties, can serve only in a qualitative way to direct the efforts towards solving the problem of atomic structure.

In the second part of the paper there has been given the mathematical development of the relation between the atomic radius and the magnetic permeability of the elements. The final form of the result shows that the area of the electronic orbits in the atom has a very simple connection with the permeability of the element concerned and the mass and charge of an electron. The limitations of the theories of magnetism are such that the result applies only for the diamagnetic elements.

Part I—*The Magnetic Properties of the Elements of the Periodic System*

As a first step in the study of the magnetic properties of the elements, a table of the elements was prepared in which were inserted the values of the atomic susceptibilities, which is the product of the specific magnetic susceptibility and the atomic weight. The results are recorded in Table I, which contains the symbols of the elements, their atomic numbers and their atomic susceptibilities, multiplied by 10^6. The values of the specific magnetic susceptibilities used in these calculations were taken from the results of Honda[1] and Owen,[2] which have been regarded as the most accurate available.

TABLE I

I	II	III	IV	V	VI	VII	VIII
H : 1							He : 2 −42·5
Li : 3 +3·47	Be : 4 −9·1	B : 5 −7·7	C : 6 −5·9	N : 7 +	O : 8 +	9 : F	Ne : 10
Na : 11 +11·7	Mg : 12 +13·4	Al : 13 +16·3	Si : 14 −3·7	15 : P −27·94	16 : S −14·6	17 : Cl −18·7	Ar : 18 −225
K : 19 +15·6	Ca : 20 +44·1	Sc : 21	Ti : 22 +57·7	V : 23 +76·6	Cr : 24 +150·8	Mn : 25 +488·9	Fe : 26 Co : 27 Ni : 28 FERROMAGNETIC
29 : Cu −5·5	30 : Zn −10·14	31 : Ga −16·78	32 : Ge −8·7	33 : As −23·25	34 : Se −25·34	35 : Br −32·0	Kr : 36
Rb : 37 +6·0	Sr : 38 −17·5	Y : 39	Zr : 40 −40·8	Nb : 41 +121·6	Mo : 42 +3·8	43	Ru : 44 Rh : 45 Pd : 46 +43·7 +113·2 +554·8
47 : Ag −21·6	48 : Cd −20·2	49 : In −12·6	50 : Sn −35·7	51 : Sb −98·6	52 : Te −40·8	53 : I −45·7	Xe : 54
Cs : 55 −13·3	Ba : 56 +123·7	La : 57	RARE EARTHS STRONGLY +	Ta : 73 +145·2	W : 74 +40·5	75	Os : 76 Ir : 77 Pt : 78 +7·6 +25·1 +156·2
79 : Au −29·6	80 : Hg −38·1	81 : Tl −48·96	82 : Pb −24·9	83 : Bi −287·2	84 : Po	85	Em : 86
	Ra : 88	Ac : 89	Th : 90 +18·6	U : 92 +619·3			

A glance at this table showed some rather striking relations, not only within the families of elements, but more general relations pertaining to the whole system of the elements. It should be remarked that the usual practice has been followed in writing the symbols for some elements on the left-hand side of the vertical column and the symbols for others on the right-hand side of the same column. This custom has been dictated by the similarities of chemical properties of the elements, as in Group I of Lithium, Sodium, Potassium, Rubidium and Caesium on the one hand, and of Copper, Silver and Gold on the other hand. Further, the paramagnetic elements have been indicated by a plus sign and the diamagnetic elements by a minus sign, in accordance with the usual notation.

[1]K. Honda, Annalen der Physik, 32, 1027, 1910.

[2]M. Owen, Annalen der Physik, 37, 657, 1912.

It will be noted that the elements which are found on the left-hand side of any vertical row show a distinct tendency to be paramagnetic. In fact, on examining the table more closely, it will be seen that there are only three exceptions of any importance, namely, Caesium in Group I, Strontium in Group II and Zirconium in Group III, if it is assumed that in Group VIII the family of the rare gases should be placed on the right-hand side of the vertical row and the family of Iron metals and Platinum metals on the left-hand side.

This deviation in the magnetic properties of these three elements must be regarded as quite unusual, since in their other chemical and physical properties they have been found to resemble strongly the other members of their respective chemical families. Thus the generalization was found to hold quite well throughout the periodic system.

On the other hand, as is readily seen, the elements which occurred on the right-hand side of any vertical row are found to be diamagnetic and there are no exceptions to this rule at all, taking the same allocation of the elements of Group VIII, as mentioned in the preceding paragraph. Further, it is at once apparent that, in every chemical family on the right-hand side of a vertical row, the diamagnetic elements tend to become more diamagnetic with increase in atomic weight. This property is especially well shown by the families Copper, Silver, Gold; Zinc, Cadmium, Mercury; Arsenic, Antimony, Bismuth; Chlorine, Bromine, Iodine and the noble gases Helium and Argon.

It is interesting to note that the recent investigations into the crystal structure of the elements, which were initiated by Hull in America and Debye and Scherrer in Germany, have indicated a somewhat similar state of affairs for the relations of the crystal structure of the element and its place in the periodic system. As Hull[3] has pointed out, as far as he was able to judge from the elements that have been analysed, there is a distinct tendency for all the elements in the same vertical column to have the same crystal structure. It is as yet too soon to attempt to explain in detail these periodic crystalline, and also magnetic, properties of the elements by any of the proposed atom models, but there can be no doubt but that the magnetic susceptibility like crystal structure and the other periodic physical properties of the elements must be represented by a similar periodic function as is their chemical behaviour. The present theories in these matters would lead us to connect these properties

[3]A. W. Hull, Jl. Franklin Institute, Feb., 1922.

with the arrangement of the extra-nuclear electrons, or possibly with the arrangement of the electrons in the outer ring or shell, which are the valence electrons.

As a result of these general observations regarding the distribution of the paramagnetic and diamagnetic properties among the elements of the periodic system, it is possible to make some predictions of the magnetic properties of the elements which have not yet been examined. For instance, it is to be expected that the elements, Scandium, Yttrium and Lanthanum on the left-hand side of Group III will prove to be paramagnetic and that the other inert gases, Neon, Krypton, Xenon and Niton will be strongly diamagnetic. It will be of some interest to discover just what are the magnetic properties of these elements.

A remarkable variation is shown in the magnetic susceptibilities of the elements of the first long period, starting with Potassium, as the atomic number increases. Potassium is slightly paramagnetic and the paramagnetism increases steadily through the elements Calcium, Titanium, Vanadium, Chromium and Manganese till it reaches its maximum in the so-called ferromagnetic elements, Iron, Cobalt and Nickel. There is then an abrupt change to diamagnetic properties in all the remaining elements in the period up to Krypton. This peculiarity is repeated in both the next two long periods and is an important point in testing theories of atomic structure. Langmuir[4] has discussed these breaks in magnetic properties in connection with his extension of Lewis' theory of atomic structure and has shown that they are incorporated in a qualitative way at least in his model.

Another way of presenting the variation of the magnetic properties of the chemical elements is shown in Fig. 1, which is the well-known atomic volume curve obtained by plotting atomic numbers as abscissae and atomic volumes as ordinates, the latter being defined as the ratio of the atomic weight to the density of the element concerned. On the line below the curve the magnetic properties of the elements have been indicated by a plus sign or a minus sign directly below the element concerned, where these signs denote para- and diamagnetism respectively. It will be seen that for all elements of atomic number greater than 10, that is, for sodium and all the heavier elements, there is a quite distinct distribution of the paramagnetic and diamagnetic elements along the curve. The paramagnetic elements without exception occur on the descending slopes of the peaks. Thus, from Sodium to Aluminium inclusive, from Potassium to

[4]Am. Chem. Soc., J. 41, pp. 868-934, June, 1919.

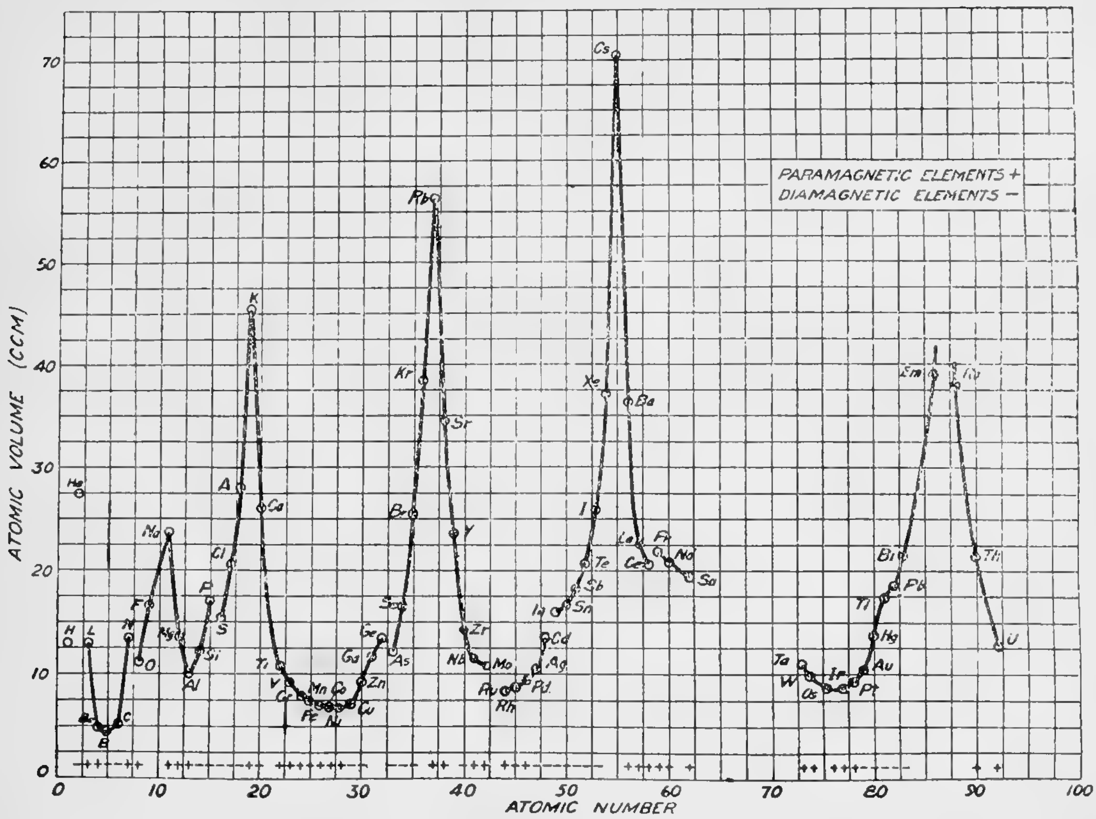

Fig. 1

Nickel inclusive, from Rubidium to Palladium inclusive (excepting Zirconium), from Barium to Platinum inclusive, and Thorium and Uranium are the groups of the paramagnetic elements. Further, the most strongly paramagnetic elements, such as the family of the Rare Earths, and the ferromagnetic elements, Iron, Cobalt and Nickel, lie in the very minima of the atomic volume curve. On the other hand, the diamagnetic elements with the sole exception of Zirconium will be found on the ascending slopes of the peaks of the curve. There is thus a very sharp demarcation in the distribution of the magnetic properties among the elements, the paramagnetic properties starting off weakly in each period then increasing to a maximum and finally the transition to diamagnetic elements in the latter part of each period. There must be in this some repeated peculiarity of the atomic structure of the elements. In a recent work by Bohr[5] on the relation of the atomic structure and the properties of the elements there is a discussion of the magnetic properties of the elements, in which Bohr expresses the opinion that "in the fourth and later periods there is a break in the very symmetrical inner structure of the atom which obtains in the earlier periods, and this lack of symmetry

[5]Bohr, Zeit. f. Physik, 9, p. 1, 1922.

prevents the magnetic forces arising from the motions of the electrons, from forming a system of closed lines of force within the atom itself." Bohr believes that the development of our ideas of atomic structure as we pass from one element to another will be greatly advanced by a careful analysis of the magnetic properties of the atoms and ions.

If, however, a curve is plotted between the magnetic susceptibilities and the atomic numbers of the elements, it will be found that, aside from the fact of their periodicity, the two curves have little in common, for the maxima of the susceptibility curve will be at those atomic numbers which are almost at the very minima of the atomic volume curve. There is practically no similarity in shape of the two curves and for that reason it has been omitted from the paper.

From the standpoint of Langevin's Theory of Magnetism it might be expected that diamagnetism, being a fundamental property of the atom, should exhibit some close relation with atomic number. With many of the elements, as such, the inherent basic diamagnetism is masked by the much larger effect of paramagnetism and this fact complicates a study of this property. Realizing this, St. Meyer, Pascal and others attempted to determine the diamagnetic susceptibilities of the atoms themselves from an examination of their compounds. It was found that an element in the pure state might be quite paramagnetic and yet in all its compounds it might have a certain amount of diamagnetism. It must be remembered, too, that in compounds we are dealing with two or more nuclei, sharing some of their electrons in common electronic orbits, which is quite a different arrangement from what is the case in the elements themselves which are believed to be mostly monatomic. There is no doubt that, though in the case of compounds it is more correctly a question of the magnetic properties of the ion rather than of the atom, in some cases, about 18 in all, there is good agreement of the values of the atomic magnetic susceptibility obtained in both ways but these are scattered through the periodic system in no definite way.

Part II—*The Atomic Diameters of the Elements.*

In the development of the theory of magnetism there have been repeated attempts to explain the magnetic phenomena by the physical interpretation of what are called molecular magnets. First Ampére and then Weber, at a time when little or nothing was known of the constitution of the atom, tried to solve the problem by the assumption of the existence of currents flowing within the atoms or molecules. Recent developments of the theory of electrons by J. J. Thomson, Rutherford and others have provided a plausible origin of these atomic or molecular currents. In fact, Bohr's theory of atomic structure, in supposing the electrons to rotate about a common centre, the nucleus, actually provides the resistanceless electric circuits which were assumed by Weber. Langevin was then able to apply this electron theory to give a fairly reasonable theory of diamagnetic and paramagnetic phenomena and a later extension by Weiss explained in a qualitative way at least the properties of ferromagnetism.

The theory can be applied at once to Bohr's model of the atom since in it the electrons are rotating. But in the case of the Langmuir atom model, which is of the static type, it is necessary to make use of a theorem due to Lorentz[6] by which it can be shown that electrons at rest in the atom will be set in motion by the superposition of an external magnetic field and then the theory of magnetism applies.

Let there be a system of electrons at rest such that their distribution is isotropic with respect to three rectangular axes of reference, which may have any orientation about the origin 0. Then this isotropism of the system may be expressed by

$$\Sigma_x = \Sigma_y = \Sigma_z = 0.$$

The moment of inertia of the electrons about any axis through the system will be

$$Q = 2\ m\ K$$

where $K = \Sigma x^2 = \Sigma y^2 = \Sigma z^2$

and $\Sigma xy\ \ \Sigma yz = \Sigma xz = 0,$

due to the isotropism of the system.

If the components of the electric field created by external causes are designated by E_x, E_y, E_z, and the assumption can be made that the system of electrons is small in dimensions, i.e., the electrons are closely clustered around the centre, 0, just as atomic theories picture them about a nucleus, then the electric force will depend on the position of the point, i.e., $E = F(x, y, z)$. On making a few simple substitutions, the components of the couple acting on an electron become

$$e\,K\left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}\right)$$

$$e\,K\left(\frac{\partial F_x}{\partial z} - \frac{\partial F_z}{\partial x}\right)$$

$$e\,K\left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)$$

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[6]Lorentz, Theory of Electrons, p. 124.

which reduce by the use of Maxwell's equations to the form

$$-e\,K\,\dot{H}.\cos\alpha;\quad -e\,K\,\dot{H}.\cos\beta \text{ and } -e\,K\,\dot{H}.\cos\gamma,$$

where cos α, cos β and cos γ are the direction cosines of the field H.

Thus there is a resultant couple $-e\,K\,\frac{dH}{dt}$ producing rotation about an axis which lies in the direction of the applied field. The solution of the equation of motion gives the angular velocity $-\frac{e}{2m}.H$. It will be noted that the rotation and its velocity are independent of the particular arrangement, subject, of course, to the condition of isotropism imposed on the whole system.

Now, since it has been shown that with either the dynamic or the static atom model there are electrons in rotation in the atom when the external magnetic field is applied, the theory of diamagnetism can be applied to calculate the magnetic susceptibility in terms of these electronic orbits.

If L is the self-induction and R the resistance of the electronic circuit and E the electromotive force produced by the application of the external magnetic field the instantaneous equation for the circuit is

$$\frac{dLi}{dt} + Ri = E.$$

But the circuits are resistanceless, i.e., $R = o$, and the applied electromotive force

$$E = -\frac{\partial B}{\partial t} = -\frac{\partial}{\partial t}(\pi r_p^2\,H\cos\theta)$$

for an orbit of radius r_p inclined at an angle θ to the field H.

Integration gives $Li = -H\,\pi\,r_p^2\cos\theta$.

Further, the magnetic energy associated with a circuit of this type is $\frac{Li^2}{2}$ and this energy must be equal to the kinetic energy imparted to the electron, i.e. $\frac{Li^2}{2} = \frac{mv^2}{2}$.

For an electronic orbit $i = e.n$, where n is the frequency of rotation, and the velocity of rotation is $v = 2\pi r_p.n$ where r_p is the radius of an orbit of type p.

Making these substitutions in the above

$$i = -\frac{H\,e^2\cos\theta}{4\pi m}.$$

The change in magnetic moment of the circuit due to this current is

$$\partial M' = -\frac{H e^2 S_p \cos\theta}{4\pi m} \quad \text{if } S_p \text{ is the area of an orbit of type } p.$$

$$= -\frac{H e^2 r^2_p \cos\theta}{4m}$$

and has a component along the direction of the field of the amount

$$\partial M'' = -\frac{H e^2 r^2_p \cos^2\theta}{4m}.$$

Then the magnetic moment contributed by the N electronic orbits per unit volume will be

$$\partial M = -\int \frac{\sin\theta\, d\,t}{2} \,.\, N \,.\, \frac{H e^2 r^2_p \cos^2 t}{4m}$$

$$= -\frac{H e^2 r^2_p N}{12m}.$$

This quantity is the induced diamagnetic moment per unit volume and by definition is equal to the intensity of magnetisation, i.e.,

$$I = -\frac{N e^2 r^2_p H}{12m} = -\frac{e^2 H}{12\pi m} . N . \pi r^2_p.$$

So far, all the orbits have been supposed to be of the one type p, but, as is known, all theories of atomic structure have assumed that this is not the case, and in considering diamagnetic phenomena we have as yet no reason for rejecting any of the electronic orbits.

Let there be n types of orbits in the atom and v_p orbits of area S_p, say. Then the expression for the intensity of magnetisation given above will become:

$$I = -\frac{e^2 H}{12\pi m} \sum_1^n v_p S_p = k . H$$

But $$B = \mu H = H + 4\pi I = H - \frac{e^2 H}{3m} \sum_1^n v_p S_p$$

Hence $$1 - \mu = \frac{e^2}{3m} \sum_1^n v_p S_p$$

$$\text{or } \sum_1^n v_p S_p = \frac{(1-\mu)\, 3m}{e^2}$$

where μ is the permeability per unit volume.

To evaluate the summation term all there is to do is to find the sum of the areas of the orbits of one atom of the substance and then multiply by the number of atoms per ccm. of the element under consideration. In applying this to Bohr's model of the atom, the radii of the various orbits have been assumed to be in the ratios of $1^2 : 2^2 : 3^2 : 4^2$:, etc., neglecting any shrinkage of the rings due to the repulsion of the electron rings, and, since the orbits are coplanar, the total area of the electronic orbits of an atom can be readily evaluated in terms of the radius of the innermost ring of electrons. But in Langmuir's model the radii of the shells are supposed to be in the ratios of 1:2:3:4, etc., and the arrangement of the electrons is spatial about the nucleus. To allow for this the radii of the orbits of the various electrons have been assumed to be on the average $\frac{1}{\sqrt{2}}$ times the distance of the electron from the nucleus. This will be quite accurate for those shells containing 8 electrons and approximately so for those containing a larger number of electrons. The distribution of the electrons in the various rings or shells of the two models is indicated by the following table of the inert gases.

TABLE II

Atom Model	Helium	Neon	Argon	Krypton	Xenon	Emanation
Bohr	2	2, 8	2, 8, 8	2, 8, 18, 8	2, 8, 18, 18, 8	2, 8, 18, 32, 18, 8
Langmuir	2	2, 8	2, 8, 8	2, 8, 8, 18	2, 8, 8, 18, 18	2, 8, 8, 18, 18, 32

The results of the calculations are compiled in Table III. There are twenty-six diamagnetic elements which lend themselves to this analysis. When once the radius of the innermost ring or shell of electrons is known it is a simple matter to obtain the value of the atomic radius, by multiplying by the proper factor, i.e., n^2 in Bohr's model or n in Langmuir's model, where n is the number of rings or shells supposed to exist in the atom. In the last three columns are given the data regarding the spacings of the atoms of the elements, as derived from X-ray crystallographic measurements. The values in the last column are those obtained by W. L. Bragg, from the analysis of chemical compounds, and thus presumably denote the radius of the ion. It will be noted that it is considerably less than the distance between atoms, given in the preceding column, which was obtained by analysis of crystals of the pure element. As regards the values obtained from considerations of magnetism it will be seen that they are of the right order in all cases and with many elements the agreement is more than fair, especially in view of the fact that the measurement of these feeble diamagnetic susceptibilities cannot pretend to the accuracy of crystal analysis, and, moreover, an error of 1 per cent. in k means a 12 per cent. error in the value of $(1-\mu)$.

TABLE III

Element	Atomic number	$(1-\mu)$ x 10^6	No. of atoms per ccm. N x 10^{-22}	$\sum_{1}^{n} \nu_p S_p$ x10^{15}.cm^2.	Radius of first orbit: Bohr model x 10^{10} cms.	Radius of first orbit: Langmuir model x10^{10}. cms.	Radius of atom Bohr model A.U.	Radius of atom Langmuir model A.U.	Length of side of elementary cube or hexagon A.U.	Data from X-Ray Analysis: Closest approach of atoms A.U.	Data from X-Ray Analysis: Atomic radius A.U.
Cu	29	10.2	8.74	1.24	4.5	16	0.72	0.64	3.60	2.54	1.37
Ag	47	25.1	6.04	4.5	4.6	20	1.15	1.0	4.06	2.876	1.77
Au	79	36.5	6.08	6.4	3.0	15	1.08	0.9	4.08	2.88	....
Zn	30	13.5	6.77	2.12	5.67	21	0.91	0.84	2.67	2.92 } 2.67 }	1.32
Cd	48	18.4	4.75	4.12	4.2	19	1.05	0.95	2.96	3.28 } 2.96 }	1.60
Hg	80	32.5	4.20	8.25	3.4	17	1.23	1.02	....	....	....
B	5	22.7	14.3	1.7	33.0	86	3.3	1.7	....	....	....
In	49	8.95	3.85	2.48	3.13	15	0.78	0.75	4.58	2.23 } 3.24 }	....
Tl	81	44.9	3.60	13.3	1.3	7	0.47	0.42	....	....	2.25
C	6	44.6	9.2	5.16	49	130	2.0	2.6	3.56	2.06	0.77
Si	14	3.66	5.24	7.44	7.2	26	0.65	0.78	5.43	2.35	1.17
Zr	40	36.5	4.41	6.84	1.9	12.2	0.5	0.6	3.23	3.18 } 3.24 }	....
Sn	50	26.5	3.04	9.3	5.8	28	1.5	1.3	6.46	2.80	1.40
Pb	82	17.3	3.41	5.3	2.5	14	0.9	0.84	4.92	3.48	1.90
P	15	20.8	3.66	6.06	19	61	1.7	1.8	....	....	....
As	33	17.9	3.92	4.87	7.4	30	1.2	1.2	....	....	1.26
Sb	51	79.0	3.41	24.7	9.2	45	2.3	2.1	4.28	{ 2.87 { 3.02	1.4
Bi	83	172.6	2.95	62.4	8.5	46	3.1	2.7	4.54	{ 3.11 { 3.47	1.48
S	16	12.6	4.01	3.35	13	4.3	1.2	1.3	....	....	1.02
Se	34	19.4	3.77	5.48	7.5	32	1.2	1.3	....	....	....
Te	52	25.5	3.07	8.83	5.3	26	1.3	1.3	....	....	1.33
Cl (gas)	17	0.0227	0.0053	4.54	15	57	1.4	1.7	....	....	1.05
Br (gas)	35	0.0340	0.0056	6.40	7.8	33	1.3	1.3	....	....	1.19
I	53	24.95	2.42	11.0	5.8	30	1.5	1.5	....	....	1.40
He (gas)	2	0.025	0.0026	10.1	160	220	1.6	2.2	....	....	....
Ar (gas)	18	0.126	0.0028	48.0	44	170	4.0	5.1	....	....	....

It is interesting to make a comparison of the values obtained from various considerations for the radii of atoms. Richards[7] has shown that the assumption of definite spherical atoms gives consistent results for the compressibilities of substances. This has led him to a calculation[8] of the size of the alkali and halogen atoms, making use of data on compressibility and contraction during chemical combination. These values for the halogens are given in Table IV.

Rankine[9] has built up theoretical models from which he has been able to calculate the atomic dimensions from viscosity measurements. Thus with chlorine he constructs a molecule by combining two argon atoms with centres 2.05 A.U. apart, as found for chlorine by Bragg from X-ray measurements. The theoretical viscosity of this molecule agrees quantitatively with the measured viscosity of chlorine. By a similar process with the other halogens he is able to deduce that the diameters of the atoms of the alkali metals and the halogens may be assumed to be the same as those of the atoms of the nearest inert gases, as obtained from viscosity measurements.

Born and Lande[10] have been able, by mathematical studies, to determine the dimensions of lattices of positive and negative ions, such as sodium and chlorine, held together by electrostatic forces. In this way they have developed a theory of atomic structure which gives the proper value of the compressibility of the salts. Bohr's theory of coplanar orbits gives a structure for the salt with twice the proper value of the compressibility. Landé is able to calculate the diameters of some atoms and his values for the halogens are included in Table IV.

Finally, W. L. Bragg[11] has made a careful and thorough analysis of the data obtained by different experimenters by X-ray analysis of different substances. His conclusion is that the experimental values can be well represented by assuming the atoms to be spheres of definite diameter, packed closely together. Bragg's values and Davey's[12] are also in Table IV.

It will be seen that the agreement among the values is remarkable, especially in view of the many different methods and hypotheses involved in their calculation. The author's results for the halogens, which were, no doubt, purer and freer from iron impurity than the

[7]Richards, Jl. Amer. Chem. Soc. 36, 2417, 1914.
[8]Richards, Jl. Amer. Chem. Soc. 43, July, 1921.
[9]Rankine, Proc. Roy. Soc., Feb., 1921.
[10]Born and Landé, Zeits. f. Physik, 1, 191, 1920.
[11]Bragg, W. L., Phil. Mag. 40, 169, 1920.
[12]Davey, Phys. Rev. 18, 102, 1921.

TABLE IV

RADII OF ATOMS (IN Å.U.)

Element	Magnetic Susceptibility Author		Viscosity	Compressibility	Atomic structure	X-ray data	X-ray data
	Bohr Model	Langmuir Model	Rankine	Richards	Landé	Davey	Bragg
Cl	1.4	1.7	1.43	1.4	1.6	1.56	1.05
Br	1.3	1.3	1.59	1.5	1.8	1.73	1.19
I	1.5	1.5	1.75	1.7	2.0	1.98	1.4

solid elements, are in good quantitative agreement with the values obtained in other ways. The values of Bragg are low, because as mentioned before, he is here dealing with the atom in combination with other atoms in situations in which they are sharing electrons in a common orbit and are thus drawn together more closely than in the pure elements.

In conclusion, the writer wishes to take this opportunity to thank Professor J. C. McLennan for his unceasing interest and stimulating enthusiasm and also the members of the Honorary Advisory Council for Scientific and Industrial Research of Canada, who, by the award of a Fellowship, have enabled the writer to continue his advanced work in Physics.

The Variation of the Refractive Index of Oxygen with Pressure and the Absorption of Light by Oxygen at High Pressures.

By MISS H. I. EADIE, M.A. and JOHN SATTERLY, F.R.S.C.

Communicated by PROF. J. C. MCLENNAN, F.R.S.C.

(Read May Meeting, 1922)

I. The Refractive Index.

The determination of the refractive index of oxygen has been carried out at moderately high pressures in order to test the relation between the refractive index and the density.

The three statements of this relation are

(1) Gladstone and Dale, $(n-1)/\rho=$ a constant
(2) Drude, $(n^2-1)/\rho=$ a constant
(3) Lorenz and Lorentz, $(n^2-1)/(n^2+2)\rho$ = a constant

A Jamin interferometer was used for the work. The instrument—made by Hilger of London—consists of the usual two parallel glass blocks of equal thickness, silvered on the back surface and mounted on a heavy metal base. The source of light was an Ediswan Pointolite lamp *P* (Fig. 2). The light, made parallel by a lens, was reflected from the mirrors *J,J* in turn and finally fell upon the slit of a Hilger constant deviation spectroscope.[1] By setting the drum of the spectroscope at any particular wave-length the fringes obtained in the field of the eyepiece or rather those at the centre of the field were produced by light of that particular wave length. As usually employed in gas refractometry the Jamin instrument is provided with two glass tubes having plane parallel glass ends. The two beams from the first mirror traverse these tubes. When the tubes are filled with the same gas at the same temperature and pressure there is no optical path difference. If, now, the gas in one tube is gradually compressed or rarefied a path difference is set up and the fringes move across the field of view.

If $f=$ number of fringes passing cross hair of telescope when the pressure in the gas drops back from *P* mms. to 760 mms., λ = wave-length of the light used (in the gas at normal pressure), $n_p,n=$ the refractive indices at pressures *P* and 760 mms. respectively, ρ_p,ρ

[1] This was calibrated from time to time with a mercury lamp.

the corresponding densities of the gas, and L = length of interferometer tubes
then

$$\lambda f = (n_p - n) L \quad \text{.........(1)}$$

Also, *if Gladstone and Dale's law is true,*

$$\frac{n_p - 1}{\rho_p} = \frac{n-1}{\rho} \text{ and } \therefore = \frac{n_p - n}{\rho_p - \rho} = \frac{n_p - n}{\rho\left(\frac{P}{760} - 1\right)}$$

$$\text{whence } n - 1 = \frac{n_p - n}{\left(\frac{P}{760} - 1\right)} = \frac{\lambda f\, 760}{L(P-760)} \quad \text{.........(2)}$$

so that n may readily be found. A temperature correction can be applied if necessary.

It is obvious from (1) that if the gas in one tube is allowed to drop from a pressure P_1 to a pressure P_2 the number of fringes crossing the centre of the field is proportional to the change of refractive index from pressure P_1 to pressure P_2.

Gladstone and Dale's law may be tested in two ways:

(1) By changing the density of the gas by the same amount at different pressures and finding the corresponding change of refractive index. If the number of fringes crossing the centre remains the same, the change of index is constant, i.e. $\frac{dn}{d\rho}$ is constant hence $\frac{n-1}{\rho}$ = a constant.

(2) By finding the absolute values of the refractivities of the gas at different densities and testing the relationship

$$\frac{n_1 - 1}{\rho_1} = \frac{n_2 - 1}{\rho_2} = \text{.................. etc.}$$

The oxygen was supplied from cylinders, 99.2% pure, the probable impurity being nitroged. The oxygen tube (Fig. 1 shows one end of tube) was of steel 28 cms. long, 3 cms. in diameter, threaded at both ends. Glass windows G (9 mm. thick) were firmly waxed into steel ends S and these could be screwed on to the tube making gas-tight joints.

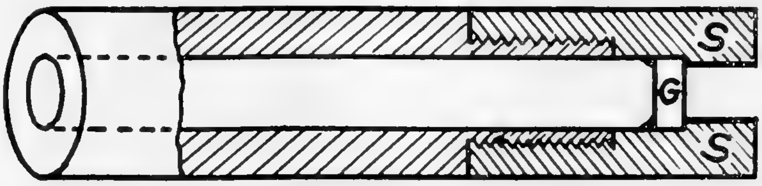


FIG. 1.

Three copper capillary tubes led from the steel tube, one F to the oxygen tank, one to a Bourdon pressure gauge G, and the other to the air through a valve V. The pressure gauge read in 25lb. steps so that it gave an approximate measure of the pressure but was not fine enough to read small pressure drops. The inlet and outlet capillary tubes were provided with needle valves so that the oxygen could be introduced and released as slowly as desired.

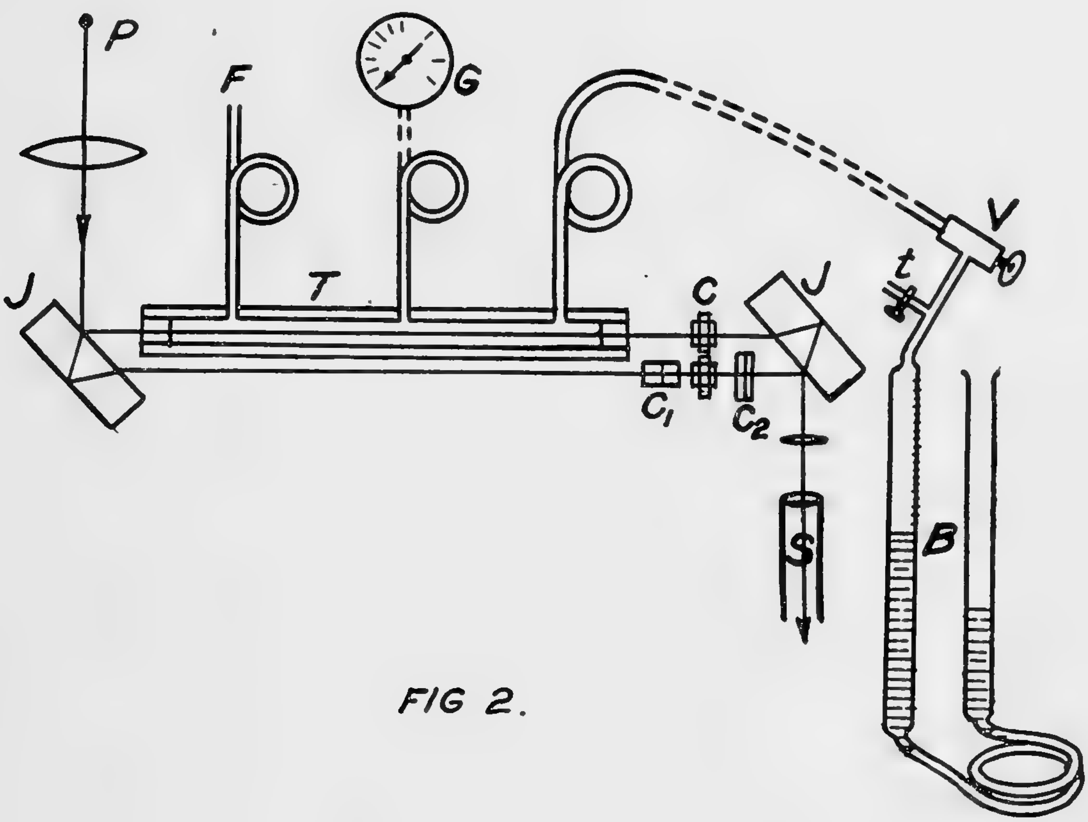


FIG 2.

The steel tube was placed in one of the interferometer beams. The other beam travelled down through the air alongside the tube. To compensate for the glass ends in the tube two similar glass ends C_1, were placed in the air beam. Also when the oxygen is at high pressure the fringes will not be seen unless compensation is again provided for by inserting glass plates C_2 in the air beam. For this purpose different thicknesses of glass were used, microscope cover slips for fine compensation, microscope slide glasses for larger compensation, and so on. If many slips of glass are used, there is a great loss of light by reflection and the fringes become very faint and uncountable. The adjustment of the compensating glasses is the chief trouble in the experiment. A variable graduated compensator would be most useful here. However, by repeated experiment and increase of experience, this difficulty was surmounted and it became possible to make large pressure changes and keep the fringes of countable clearness and size all the time.

To measure the changes of density as the oxygen is released the outlet valve was connected to a Hempel gas burette *B* by means of a glass *T* piece provided with a stop cock (Fig. 2). The burette contained water and readings were always taken when the water surfaces were level. By letting equal volumes of gas escape from the steel tube to the burette, the density of the gas was decreased by equal amounts. Correction could be applied for slight variations from this, also for temperature, humidity and so on.

The volume of the steel tube and connections up to the two needle valves was determined by a volumenometer method. It was about 75.0 cc. so that it could be arranged with each run of the burette that the pressure drop was practically one atmosphere.

Series I.

Table I. gives the number of fringes crossing the centre of the field of view of the spectrometer for one atmosphere pressure drop at the pressures named and the wave-length setting of the spectrometer.

TABLE I.

Gauge Pressure Pds. per sq. in.	No. of fringes per one atmosphere drop in the pressure.		
	$\lambda = 6258$ A	$\lambda = 5800$ A	$\lambda = 5350$ A
30	88.3	94.2	102.4
350	88.8	98.0	106.1
550	88.7	95.5	106.2
1150	88.7	94.3	105.2
1475	87.0	94.0	102.3
2000	91.1	99.8	106.1

The numbers in each wave-length column are practically constant, thus varifying Gladstone and Dale's law. Corrections were not made for variation of atmospheric pressures, temperature and humidity; this might be the reason for the slight variations observed. The mean values were used to work out the refractive index of oxygen at normal pressure.

Table II. gives the values and those obtained by other experimenters.

TABLE II.

Wavelengths	Koch	Cuthbertson	The Authors
6285 A.U.	1.002687	1.002702	1.00269
5800 A.U.	1.002697	1.002702	1.00270
5350 A.U.	1.002700	1.002719	1.00274

Series II.

One afternoon and evening a set of continuous readings was taken starting at a pressure of about 650 pds. per sq. in. and running down to atmospheric pressure. The fringes passing the cross hair during each step were counted and the volume escaping into the burette read. Continual adjustment of the compensating glasses was necessary and in some cases the fringes were not as clear as in others, no doubt it is this which causes the variation of the numbers in the last column.

No. of Fringes	Volume of Gas	Ratio No. of Fringes /100 cc.	No. of Fringes	Volume of Gas	Ratio No of Fringes /100 cc.
A 141	96.1	146.2	118	89.8	131.7
52	37.5	138.4	120	89.8	133.8
121	84.4	143.3	120	89.7	133.9
126	86.6	145.3	C 120	88.6	135.1
126	90.2	139.6	101	75.0	134.5
100	71.0	141.0	131	96.1	136.2
52	36.0	144.4	130	97.0	134.0
B 128	94.0	136.2	131	97.0	135.0
109	79.8	136.4	60	45.8	133.2
125	93.2	134.0	110	82.0	134.0
125	93.3	134.0	41	28.8	142.2
99	73.0	135.6	110	80.6	136.2
125	92.6	135.0	99	74.0	133.9
88	66.2	132.5	99	74.2	133.8
136	101.8	134.0	126	95.8	131.8
99	74.0	134.0	120	87.3	137.5
124	94.2	131.6	129	94.6	136.2
120	89.8	133.8	47	33.6	139.8
120	88.0	136.2			

This gives a total of 4028 fringes counted and a volume of 2961.4 ccs. of oxygen escaped.

The corrected spectrometer reading was 5210 A.U.

The atmospheric pressure was 750 mm. and the temperature 21°C.

The saturation vapour pressure at 21°C. is 19 mm.

If L is the length of the tube and x_1, x_2, are the number of wave-lengths in the gas and in the air respectively then we have

$$L = x_1 \lambda_1 = x_2 \lambda_2$$

where λ_1, λ_2, are the wave-lengths of the light on the two sides. Let n_1, n_2, be the refractive indices of the gas and the air respectively and λ_0 the wave-length in vacuo of the light used. Then

$$L = x_1 \frac{\lambda_0}{n_1} = x_2 \frac{\lambda_0}{n_2} \text{ and } \therefore = \frac{x_1 - x_2}{n_1 - n_2} \lambda_0$$

$$\text{or } n_1 - n_2 = \frac{\lambda_0}{L}(x_1 - x_2).$$

$x_1 - x_2$ is the number of fringes that would cross the field if the gas were replaced by air, or what comes to very nearly the same thing if the pressure of the oxygen were lowered to atmospheric pressure. The index for air for $\lambda = 5210$ Å.U. is taken as 1.000294.

Selecting at random 3 states of the gas indicated by A.B.C. in the table, we have calculated the refractive index of the gas in those states using the formula

$n - 1.000294 = \frac{\lambda_0}{L}$(number of fringes from the given state down to atmospheric pressure).

1	2	3	4	5	6	7	8	9
	No. of fringes down to atmospheric.	Volume of gas run out.		Total volume of gas in tube if measured at atmos. pres. (750 mm.)	Pressure in atmos.	Density of the gas gm. per c.c. ρ	$n-1$	$\frac{n-1}{\rho}$
		As measured.	Corrected for humidity					
		c.c.	c.c.	c.c.				
A	4028	2961	2884	2959	39½	.0517	.01000	.1934
B	3310	2460	2397	2472	33	.0432	.00827	.1914
C	1554	1150	1120	1195	16	.0209	.00404	.1935

Column 4 is obtained by multiplying column 3 by $\frac{731}{750}$.

Column 5 is obtained by adding 75 cc. to column 4.

Column 6 is an approximate value of the pressure obtained by dividing Column 5 by 75.

Column 7 is obtained from Column 5 by multiplying the numbers in Column 5 by the density of oxygen at 21° and 750 mm. to get the total mass of oxygen and then dividing by the volume, 75 cc. to get the density in gm. per cc.

Column 8 is obtained from the optical equation above.

Column 9 gives the value of $(n-1)/\rho$. It is seen to be practically constant thus verifying the law of Gladstone and Dale for oxygen up to a pressure of nearly 40 atmospheres. The mean value of the constant is .192.

Previous Work of a Similar Character.

P. Phillips (Proc. Roy. Soc., Vol. 97) gives an account of work done by him to find the relationship between the refractivity and density of carbon dioxide. He used a Fabry and Perot etalon placed within a strong metal chamber with glass windows. In order to work over a large range of density he kept the temperature just above the critical temperature cf carbon dioxide. Proceeding in much the same way as described above he measured the continuous change of refractivity from a density of .73 gm/cc. downwards. His results for $\lambda=5461$ A.U. conform to the law

$$\frac{n^2-2}{n^2+1}\rho = 6.581+.1130\rho^2$$

This for small values of ρ is in agreement with Lorenz and Lorentz's expression.

C. and M. Cuthbertson (Proc. Roy. Soc., Vol. 83) used a Jamin interferometer and worked between pressures of 0 and 760 mm. From their data the value of $\frac{n-1}{\rho}$ for $\lambda=5210$ A.U. is found to be 0.190.

Rentschler (Astrophysical Journal, Vol. 28, 1908) used a Fabry and Perot interferometer and pressures less than atmospheric. From his data the value of $(n-1)\ \rho$ calculated for $\lambda=5210$ A.U. is 0.191.

It will be seen that our value of $(n-1)/\rho$ is in close agreement with those of Cuthbertson and Rentschler and we have shown that it remains constant up to a pressure of at least 40 atmospheres.

Future Work

To carry out work at higher pressures a double tube made by boring two $\frac{3}{8}''$ holes through a steel rod $10''$ long and $2''$ diam. will be used. Great trouble was experienced in getting the windows at the ends of these tubes plane-parallel and gas-tight up to a pressure of about 120 atmospheres but success was reached at last. By filling both tubes with high-pressure gas and letting the gas out alternately from the two sides the optical compensation will be made quite easy.

II. *Absorption of Light by Oxygen.*

The absorption spectrum of oxygen at high pressures has been studied by Liveing and Dewar[1], Olszewski[2] and others, who found that with a pressure of 85 atmospheres, there was a number of bands in the visible region and a complete absorption in the ultraviolet, beginning about the wave-length $\lambda = 2664$ Å.U. When the pressure was increased to 140 atmospheres, the bands in the visible were intensified: an additional faint band was brought out in the indigo, and complete ultra-violet absorption now began at the wave-length $\lambda = 2704$ Å.U. In Liveing and Dewar's experiment, the absorption chamber consisted of a strong steel tube, 65 cm. in length with quartz ends so that the ultra-violet rays were included in their observations. The source of light was placed about the middle of the tube and held in place by means of three springs. This lens was of the required focal length to focus the image of the source on the slit of the spectroscope. The spectrum so obtained was then photographed. Later they worked with a tube of oxygen 18 metres in length. With this they were able to observe the absorption bands at much lower pressures. The quantity of oxygen in the tube at the highest pressure used was about equal to that traversed by the sun's rays in passing through the atmosphere when the sun is vertical.

This work was repeated with slightly different arrangement of apparatus by Mr. W. W. Shaver[3] of the University of Toronto under

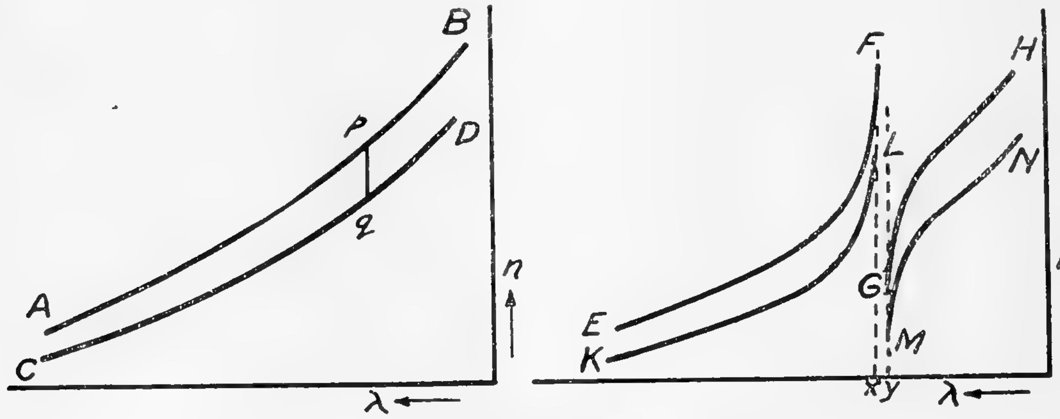


FIG. 3.

[1]Liveing and Dewar, Phil. Mag. 26, p. 387, 1888; Phil. Mag. (5) 34, p. 205, 1892.
[2]Olszewski, Wied. Ann., 42, p. 663, 1891.
[3]W. W. Shaver, Trans. Roy. Soc. of Canada, Vol. XV., Third Series, 1921.

the supervision of Professor J. C. McLennan. Slightly different values for the wave-lengths of the absorption bands than those found by Liveing and Dewar, were obtained.

The bands observed in the visible spectrum were:

Liveing and Dewar. A.U.	McLennan and Shaver. A.U.
6305	6285
5785	5800
5350	5350
4773	4816
4470	
	3828

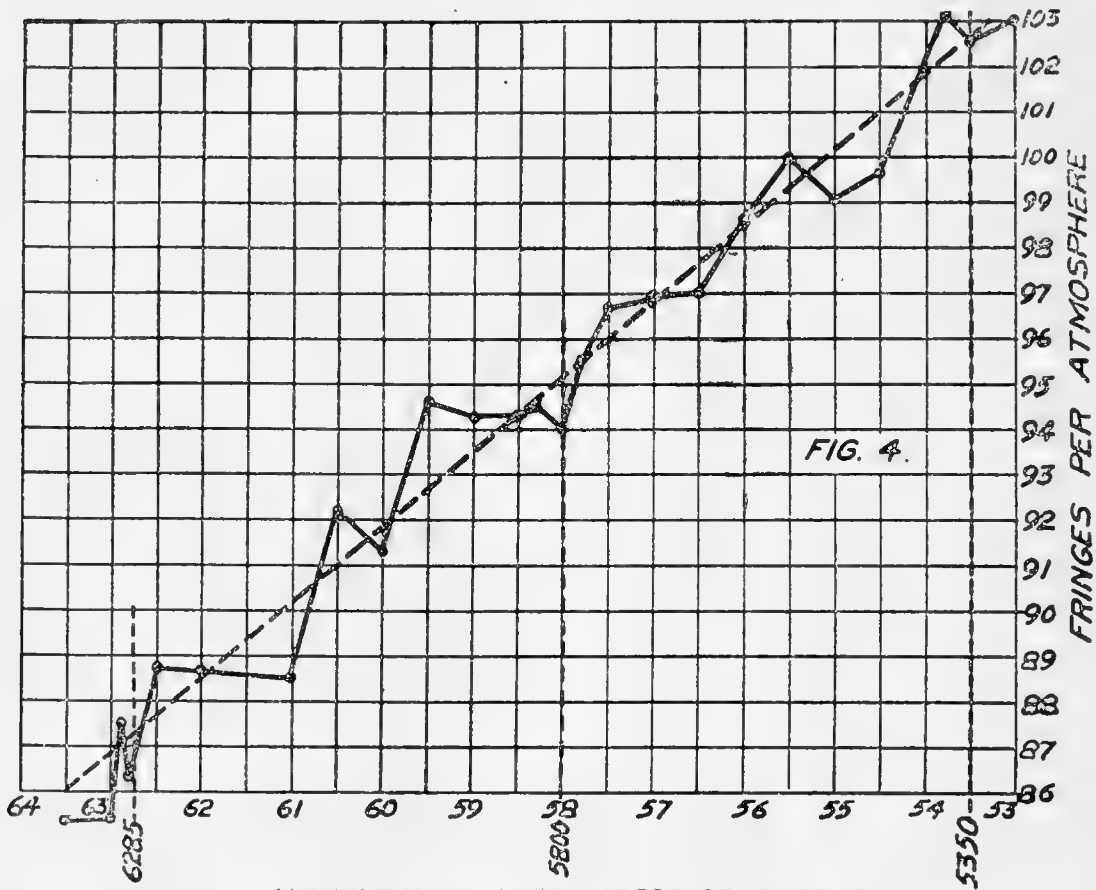
An endeavour was made with the Jamin interferometer to detect these absorption bands by means of the changes in the refractive index of the gas in the immediate neighbourhood of the absorption bands.

Line $A B$ left-hand Fig. 3 shows for some particular pressure the variation of n with λ for a gas showing no absorption band. $C D$ shows the variation at a lower pressure. The vertical line $p\ q$ indicates the change of index for a particular λ when the pressure drop is made. This change of index is proportional to the number of fringes passing the centre of the field of view. Table I. indicates the results obtained when the pressure drop was practically one atmosphere. The number of fringes changes gradually as the λ of the light used is altered.

The broken lines $E\ F\ G\ H$ and $K\ L\ M\ N$ show the curves for two pressures when the gas has an absorption band at the position indicated by $x\ y$. It was thought that there may be a marked change in the vertical distance between $E\ F\ G\ H$ and $K\ L\ M\ N$ as the absorption band was crossed.

The interferometer tube described in the first part of the paper was accordingly filled with oxygen at a pressure of 1475 lbs./in.^{2} Readings were taken for pressure changes of an atmosphere, for wave-lengths right across the spectrum in a region which included the wave-lengths of the three absorption bands found by Liveing and Dewar, McLennan and Shaver, as stated above. These bands were of wave-lengths 6285, 5800, 5350 Å.U. They were the only ones in the region of visibility of the interferometer. At the pressure of 100 atmospheres, the 5800 band appeared as an extremely faint narrow line; the 6285 band did not show up and the 5350 band was scarcely perceptible. The intervals between successive spectrometer settings were sometimes as small as 20 Å.U.

Fig. 4 shows the curve obtained by plotting the change in refractive index for 1 atmosphere change in pressure against the wave-length of the light used. This curve shows dips at the wave-lengths where the absorption bands occur but there are dips at other places



and it looks as if the observed variations in the change in refractive index for 1 atmosphere change in pressure close up to the absorption band are of the same order as the experimental errors; therefore no conclusions can be drawn from these results.

It follows from this that in order to detect any variation in the change in refractive index corresponding to that shown in Fig. 3, it would be necessary to find the *absolute* values of the refractive index for ranges of, say, 5 Å.U. right across the estimated position of the absorption band. This would entail counting about 6000 fringes for each reading and clearly a photographic method might with advantage be used.

In conclusion, the writers desire to express their sincere thanks to Professor J. C. McLennan for suggesting this experiment and providing the necessary apparatus.

Physical Laboratory,
University of Toronto,
June 1st, 1922.

The Crookes Radiometer

By JOHN SATTERLY, F.R.S.C.

(Read May Meeting, 1922)

In a series of six papers published in the Philosophical Transactions for the years 1873–1879,[1] Sir William Crookes described the long series of experiments that he made on Repulsion arising from Radiation. Partway through the work (in 1874) he invented the Radiometer or Light Mill, a little apparatus consisting of a light movable vane system delicately pivoted and mounted in a vacuum tube. In the usual form of instrument there are four mica vanes mounted on four arms at right angles to each other. The vanes are blackened at one side and mounted vertically and radially at the ends of the arms so that when the mill is set spinning the blackened surfaces are all advancing or all retreating. When exposed to a source of radiation, e.g. the sun, or a lamp, or a hot ball, the mill turns in such a way that the blackened surfaces are apparently repelled by the radiation more than the untreated surfaces. In 1875 Crookes measured the rates of rotation for a particular instrument placed at different distances from a constant source of radiation (an oil lamp) and enunciated the law that the speed of rotation was proportional to the intensity of the incident beam. He varied the experiment by arranging a number of candles in a circle of 2ft. diameter round a radiometer and starting with all the candles burning he blew them out one by one and measured the corresponding speeds of rotation. He mentions that he did not make the experiments with any great degree of preciseness but they taught him just what he wanted to know, namely, that the instrument could be used as a Radiometer. He suggested that the Light-mill might be used as a photometer, also by photographers as an exposure meter.

If we assume for a moment that Crookes' lamp acted as a point source, the intensity of the radiation at a distance D would be inversely proportional to D^2. Crookes plotted Times of Rotation T in seconds as abscissæ and Distances D as ordinates. The points lie on a curve which fits fairly well to a parabola $D^2 = kT$ whence Crookes concluded

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[1]Vol. 163, p. 295; Vol. 164, p. 501; Vol. 165, p. 519; Vol. 166, p. 325, Vol. 169, p. 243; Vol. 170, p. 87, Vol. 172, p. 387. Also Phil. Mag. August, 1874. Proc. Roy. Soc. XXV., p. 136 and p. 304.

that the instrument behaved as a radiometer, the Speed of Rotation being proportional to the intensity of radiation.

The agreement of the points with the curve was, however, much better for large values of D and T than for small values, the points for small values lying on a curve which does not go through the origin. The small values of D and T represent large intensities and speeds and to show them more clearly on a graph I have taken Crookes' data and plotted Revolutions per minute (R.P.M. or N.) as abscissæ and the inverse square of the Distance as ordinates. Fig. 1 gives the plot. The upper inset graph shows that for small intensities and speeds the inverse law held and that the R.P.M.

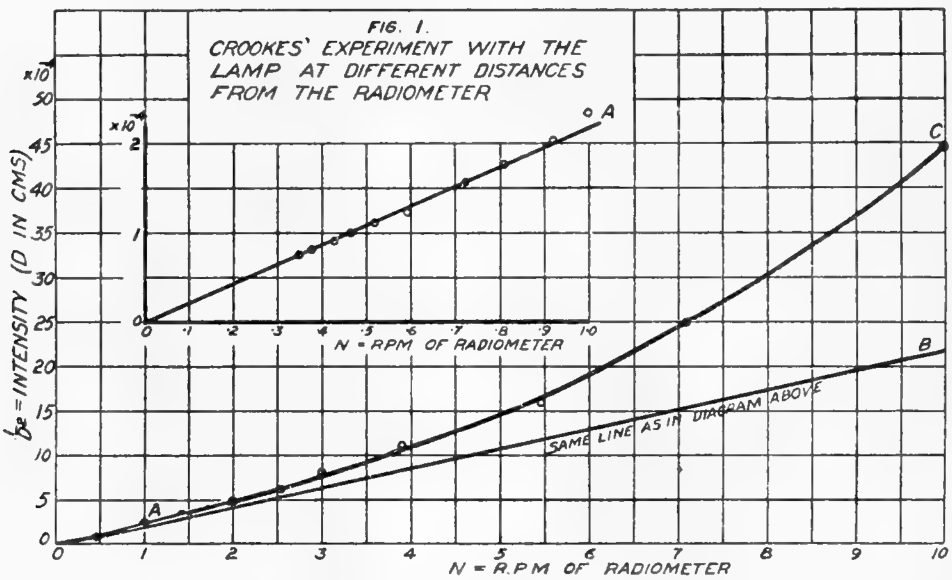

FIG. 1.
CROOKES' EXPERIMENT WITH THE LAMP AT DIFFERENT DISTANCES FROM THE RADIOMETER

were proportional to the intensity. The larger graph departs from this straight line ($O\ B$ in the large graph corresponds to $O\ A$ in the small one.

For large speeds (small distances) the graph is far from straight, the speeds being less in proportion than the corresponding value of $\frac{1}{D^2}$. Either for great speeds the R.P.M. are not proportional to the radiation or for such small distances we cannot assume that the radiation from a candle is proportional to $\frac{1}{D^2}$.

For his Circle of Candles experiment, Crookes plots Times of Rotation as abscissæ and Number of Candles as ordinates and gets practically a hyperbola.

Replotting with R.P.M. as abscissæ and number of candles as ordinates, I get Fig. 2, which shows a good average straight line

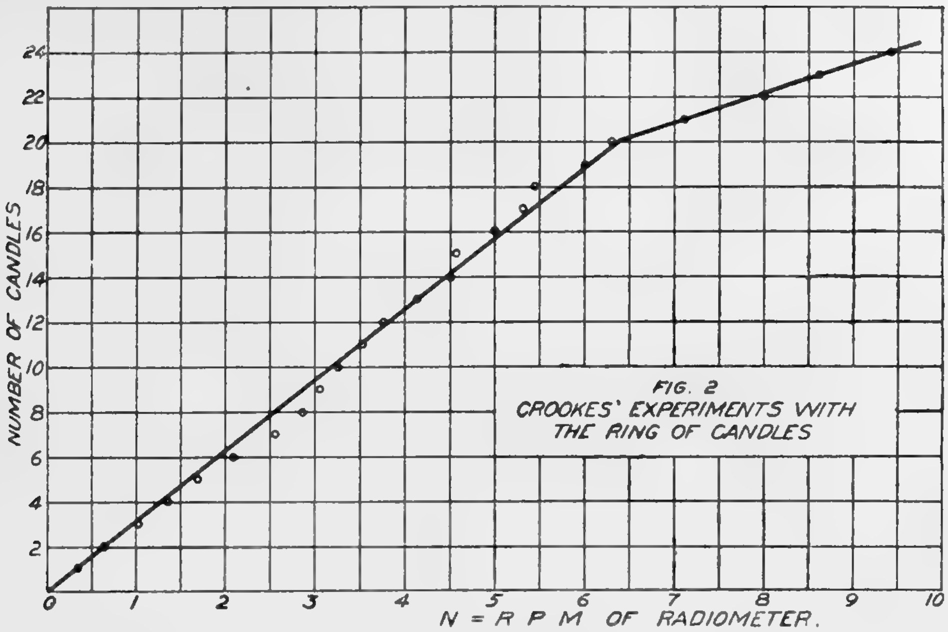

FIG. 2
CROOKES' EXPERIMENTS WITH THE RING OF CANDLES

up to 6 R.P.M. beyond that the R.P.M. seem to increase at a greater rate than the number of candles.

The Radiometer was studied at an early date by Schuster[2] and Osborne Reynolds[3], both of Manchester. They criticised the theory Crookes had put forward to explain its action and the controversy was quite keen. They tried to elucidate the actions going on within the instrument, to find out how much the motion is due of to *external* forces, how much due to *internal* forces, and the exact parts played by the vessel, the remaining gas and the surface of the vanes. In one experiment the radiometer was floated in water. A stream of radiation was allowed to act upon it and the vanes prevented from rotation by holding a bar magnet above the instrument (an iron wire had been tied to two of the arms). They found that the instrument rotated in the opposite direction to that in which the vanes would have gone if they had been free. *They concluded that the action and reaction are wholly internal or in other words that no external force acts on the light mill.*

Reynolds took up the question as to the relative parts played by the friction at the pivot and the friction by the residual gas. If the pivot friction were the only friction present the speed would go on increasing. But experiment shows that the speed gets steady, this indicates that the remaining air exercises retardation, and Reynolds, following Maxwell, showed that for the moderately low vacua used the friction was proportional to the speed even up to the high speeds obtained in the radiometer.

[2]Phil. Trans. Roy. Soc., Lond., Vol. 166, 1876, p. 715.
[3]Phil. Trans. Roy. Soc., Lond., Vol. 166, 1876, p. 725.

Lord Rayleigh[4] believed that discrepancies were still outstanding in the action of the Radiometer and hoped that the memoirs quoted above would be critically examined and the whole question rediscussed.

G. D. West[5] has also examined the radiometer and using the ideas of thermal transpiration developed by Reynolds, Sutherland and Knudsen has shewn how to explain radiometer phenomena.

Denoting the pivot friction by P (P is independent of speed), the revolutions per minute by N, the gas friction by kN, the power of the source (point) by I and the distance from the source to the radiometer by D, we get, on equating the force responsible for the motion to the forces opposing the motion

$$\frac{I}{D^2} = P + kN$$

If D_1 is the least distance at which we just get no motion

$$\frac{I}{D_1^2} = P$$

whence

$$\frac{I}{D^2} = \frac{I}{D_1^2} + kN$$

or

$$\frac{1}{D^2} = \frac{1}{D_1^2} + k'N.$$

Plotting $\frac{1}{D^2}$ against N we should get a straight line.

The author has carried out several experiments using as sources iron balls heated red hot in the flames of Meker burners. The flames by themselves have a temperature between 1600–1700°C., the balls would of course be at least 500°C. lower than this. Two sizes of balls were used of diameter 7.8 cm., and 4.2 cm. respectively. The flames practically enveloped the balls.

Two types of Radiometer were employed, No. 1 has mica vanes blackened on one side, No. 2 has aluminium vanes faced on one side with mica. With No. 1 the blackened surfaces retreat from the heated body, with No. 2 the polished metal retreats.

Sometimes a Fery Radiation Pyrometer was set to view the ball to test the constancy of its radiation, and sometimes also another radiometer similar to No. 1 was set up at a fixed distance from the ball to see whether the gradual heating of the glass envelope would cause any variation in the speed. Apparently it doesn't.

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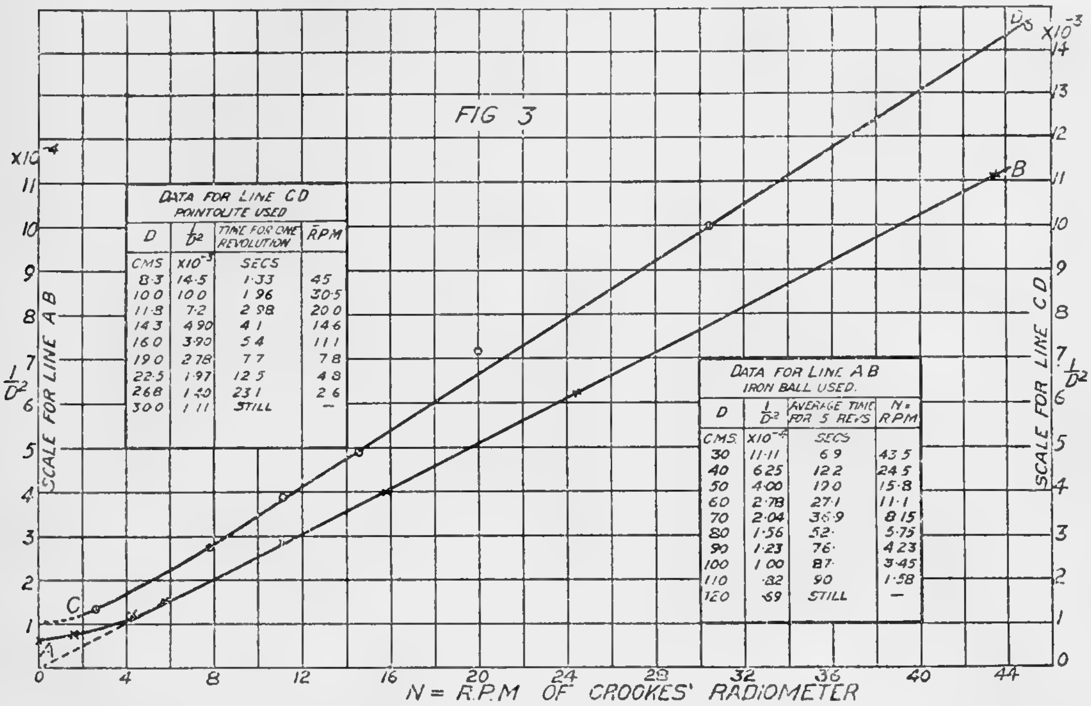
[4]Nature, Vol. 81, 1909, p. 69.

[5]Proc. Lond, Phys. Soc., Vol. XXXI, p. 278; Vol. XXXII, pp. 166, 222.

Fig. 3 curve *AB* is a sample of the curves obtained with the larger iron ball.



DATA FOR LINE CD
POINTOLITE USED

D	1/D²	TIME FOR ONE REVOLUTION	RPM
CMS	X10⁻³	SECS	
8·3	14·5	1·33	45
10 0	10 0	1 96	30·5
11·8	7·2	2 98	20 0
14 3	4 90	4 1	14 6
16 0	3·90	5 4	11 1
19 0	2 78	7 7	7 8
22·5	1·97	12 5	4 8
26 8	1 40	23 1	2 6
30 0	1 11	STILL	—

DATA FOR LINE AB
IRON BALL USED.

D	1/D²	AVERAGE TIME FOR 5 REVS	N = RPM
CMS.	X10⁻⁴	SECS	
30	11·11	6 9	43 5
40	6 25	12 2	24 5
50	4·00	19 0	15·8
60	2·78	27·1	11·1
70	2·04	36·9	8 15
80	1·56	52·	5·75
90	1·23	76·	4 23
100	1 00	87·	3·45
110	·82	90	1·58
120	·69	STILL	—

The distances were measured from a vertical plane about $\frac{1}{3}$ radius of the ball back from the front point to a vertical plane about $\frac{1}{3}$ length of the arms of the mill in front of the axis of rotation.

For small distances the points lie on a straight line (herein differing from Crookes' results). For large distances the points diverge from the straight line (herein also differing from Crookes); they lie on a curve which turns towards the intensity axis. The R.P.M. decrease in greater ratio than the intensity and when the intensity reaches a certain low value the vanes do not rotate at all.

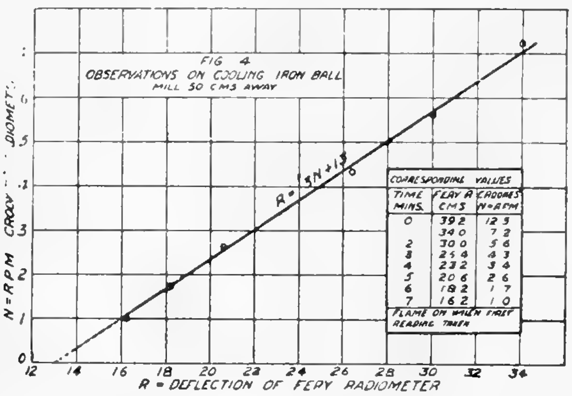
The equation of the curve obtained in one case (*AB*, Fig. 3) is

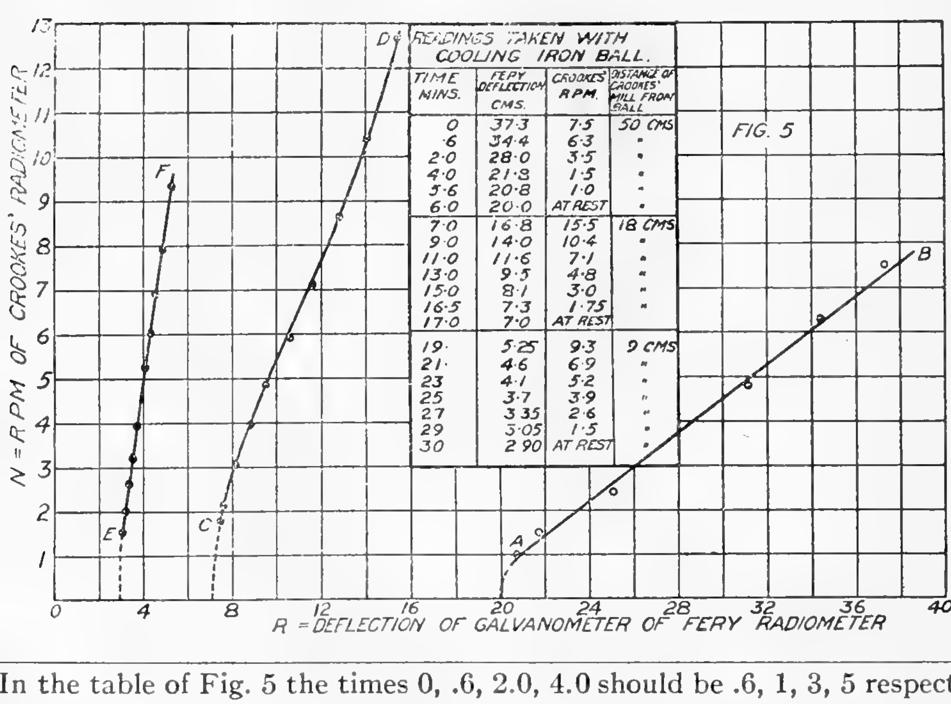
$$\frac{1}{D^2} = .000025\,N + .000075 \times 10^{-.18\,N}$$

There does not seem to be any special meaning to the exponential term and the explanation of the departure from the straight line has still to be made. It cannot be due to any departure of the calculated intensities from the real values for at these distances (80 cms. and over) the inverse square law could be applied to an iron ball of the size used.

To check this point an Ediswan pointolite source was used. This gives the graph *CD* of Fig. 3, which is also a straight line except near *C*.

Experiments were also carried out on the cooling of the larger ball from the temperature of red heat downwards. The radiation was measured both by the Light Mill and a Fery Radiation pyrometer. As timed readings were made alternately on these instruments, simultaneous values of their readings had to be made from a time chart. The results are shown in Figs. 4 and 5, where the abscissæ are the galvanometer deflections with the Fery instrument and the ordinates are the R.P.M. of the Mill. In Fig. 4 the Mill was placed 50 cms. away from the ball. For fig. 5 at first the Mill was 50 cms. away and when it ceased to revolve at this distance it was moved up to 18 cms. distance and when it ceased to revolve at this distance it was moved up to 9 cms. In this way the three graphs *AB*, *CD*, *EF*, were obtained. During this experiment the room temperature was 25°C., and the temperature about one foot away from the ball varied from 36° to 30°C.*





*In the table of Fig. 5 the times 0, .6, 2.0, 4.0 should be .6, 1, 3, 5 respectively.

The graphs are practically straight lines over a large part of their paths. The lines do not go through the origin however, and the equation is of the type

$$R = kN + m.$$

For the curve shown in Fig. 4.

$$R = 3N + 13.$$

The constants are arbitrary, depending on the experimental conditions.

Similar curves were obtained with Radiometer No. 2. But it is not as sensitive as No. 1.

Summary

1. When Crookes' Radiometer is used to measure the radiation at different distances from a red-hot iron ball and values of $\frac{1}{D^2}$ are plotted against the R.P.M. the graph is practically straight and goes through the origin except for speeds less than 5 to 7 R.P.M. (for the particular instrument used). Below this speed the R.P.M. fall off more quickly than the intensity. For this purpose the Crookes' Radiometer is interesting as a class experiment.

2. When the Crookes' Radiometer is used to take the cooling curve of a red-hot iron ball and its readings are plotted against those of a Fery Radiation Pyrometer joined to a sensitive galvanometer the curve obtained is practically straight over large portions, but unless the Mill is placed close to the ball its readings cease at a comparatively early stage of the experiment. It may be moved nearer to the ball and another set of readings taken, giving another straight line. Therefore for the cooling experiment we may only say:—"Decrease in R.P.M. is proportional to Decrease in Intensity of the Radiation."

University of Toronto.

On Surface Tension, Surface Energy and Latent Heat

By JOHN SATTERLY, F.R.S.C.

(Read May Meeting, 1922)

In the Philosophical Magazine of January, 1858, J. J. Waterston, Esq., wrote a paper on "Capillarity and its relation to Latent Heat." His argument was that "if the capillarity of a liquid is the exhibition of part of the cohesive force of the superficial stratum of its molecules, numerical relations with the latent heat of its vapour ought to be demonstrable if latent heat is the measure of liquid cohesion."

Experiments to determine the capillary constant are described in the paper. They were of two kinds (1) capillary ascents between plates and in tubes, (2) capillary pulls on plates immersed vertically in the liquids. The effect of change of temperature was also carefully studied. Waterston selected the inch as the unit of length and the weight of the grain as the unit of force. Both Fahrenheit and Centigrade scales of thermometers were used and the paper must be carefully watched for the scales of temperature.

Waterston expressed the capillary constant in a manner very different from that employed at present. In one experiment, where a spiral strip of paper 10 inches long was suspended from one arm of a balance so that the lower edge dipped in water, he found that when "the level of the water surface was adjusted so that the spiral edge of the paper should separate from it at the turn of the beam, the difference of weight just at the separation and immediately after was found by careful observation to be exactly 38 grains. This being the weight of .1505 cubic inch of water at the temperature 86°F. (the work was done in the tropics), shows the volume raised by a water line 20 inches long. For an inch the volume$=.00752$ or $1/132.9$ of a cubic inch. The value of the quotient of capillarity, Q is 132.9."

This means that the pull along a wetted-line 132.9 inches long is equal to the weight of a cubic inch of water.

"The weight of the whole column hangs, as it were, upon the water line and is equilibrated by the cohering energies of one ring line of molecules."

We should say:

If T=surface tension in grains per inch

ρ=density of water in grains per cubic inch

$$20\,T=38$$

$\therefore T = 1.9$ grains per inch.

The number of inches that must be taken before the pull is equal to ρ grains $= \frac{\rho}{1.9} = \frac{\rho}{T}$

Waterston's Q thus equals $\frac{\rho}{T}$.

Further he applied the principle of virtual work to a column of water in a capillary tube and deduced the formula $Q = \frac{4}{dh}$, where we should deduce the formula $T = \frac{\rho dh}{4}$. His experiments gave practically the same value for Q as above.

If we calculate a correct value of Q at 86°F. (=30°C.) from the present accepted value of T, viz., 71 dynes per cm. we get $Q=90$ instead of Waterston's 132.9, or working from Waterston's Q back to C. G. S. units we get $45\frac{1}{2}$ dynes per cm. Hence he was about 30% in error.

It is curious to read that Waterston himself got $Q=88$ for very narrow tubes $\frac{1}{45}$ inch in diam., but he concludes that such narrow tubes give abnormal results.

Selecting Q as 132 he says a better value of the 20 inch pull would be 38.26 grams. Waterston then advances from pulls to energies and says that "to denude 20 sq. inches of surface would require 38.26 grains descending one inch; or to denude 1 sq. inch, 1.9131 grains descending one inch vertical. This being the weight of .007577 cub. inch of water this volume of water raised through one inch is equivalent to the work of denuding a superficial stratum of one square inch, of overcoming the integral cohesion force *on one side*—the outer side—of a superficial stratum of molecules; being one sixth of the cohesion integral of all the molecules in the stratum."

The cohesion integral of one layer of the cubic inch is therefore .04546 cubic inches raised one inch. "On applying heat to water to convert it into vapour we overcome the cohesion force of all the molecules and the quantity of work which this is equivalent to, we can readily compute from the data afforded by M. Regnault and Mr. Joule, assuming that the latent heat of steam be the cohesion integral of all the molecules while in the liquid state. Thus, having the cohesion integral of one stratum of a cubic inch and the cohesion stratum of *all* the strata in a cubic inch, we obtain the number of strata in an inch and have the absolute volume of an aqueous molecule."

"From Regnault's empirical formula the latent heat of aqueous vapour at 86°F. is 1054. One cubic inch of water thus heated is equivalent to one cubic inch of water at temperature 86° raised through $1054 \times 772 \times 12$ inches vertical. . . . . Hence

$$\frac{1054 \times 772 \times 12}{.04546} = 214{,}800{,}000$$

is the number of layers of a molecule in one cubic inch, and the cube of the reciprocal of this is the absolute volume of one molecule of water at the temperature 86°. The process expressed by symbols is $m^3 = \left(\frac{6}{Q\dot{L}}\right)^3$ in which $\dot{L}$ is the product of the latent heat by 12 times 772. Q the quotient of capillarity and m^3 the molecular volume expressed with reference to a cubic inch as unit."

Expressed in modern language this would read $m^3 = \left(\frac{6T}{\rho L}\right)^3$.

Waterston's result expressed in cms. is $m = 1.47 \times 10^{-8}$ cm. He worked out a similar value for alcohol, taking $Q = 228$ and obtained

$$m = \frac{1}{146{,}000{,}000} \text{ inch which} = 1.74 \times 10^{-8} \text{ cm.}$$

Waterston also compared the molecular volumes of water and alcohol. From the above calculations he found "ratio of molecular volumes of water and alcohol equal to $\left(\frac{146}{215}\right)^3 = \frac{1}{3.18}$. He also computes it from

"Specific gravity of water at 68°F. = 1.000
" " " " " 86°F. = .998
" " " alcohol " 86°F. = .780
" " " steam = 9
" " " alcohol vapour = 23.16

whence ratio of molecular volumes $= \frac{9 \times .780}{23.16 \times .998} = \frac{1}{3.29}$"

He mentions that the two methods of calculating the relative molecular volumes did not agree with turpentine, ether, and acetic ether and ascribes it to one part of the molecule separating from the other while rising into vapour. "We must be prepared to view as possible a certain absorption of heat in partially separating, not only the molecules, but their constituent chemical elements, because the application of extreme heat alone is capable of effecting their complete separation."

The effect of change of temperature is then considered both upon the value of Q and the value of L. Waterston experimented upon liquids in critical temperature tubes of the Cagniard de la Tour pattern, and shewed that the meniscus flattened out many degrees below the point of transition and became convex on further heating.

From $m = \frac{6}{QL}$ he deduces

$$\frac{\delta m}{m} = \frac{\delta L}{L} - \frac{\delta Q}{Q}$$

and from the capillary tube equation $Q = \frac{4}{dh}$

$$\frac{\delta Q}{Q} = -\frac{\delta h}{h}$$

$$\text{whence } \frac{\delta m}{m} = \frac{\delta h}{h} - \frac{\delta L}{L}$$

and he attempts to fill in these temperature coefficients from the experiments of M. Wolf, M. Despretz and M. Regnault with, however, only partial success. Waterston takes $\frac{\delta m}{m}$ as the expansion of the liquid per unit volume. (I think here he left out a term which should have been considered, namely the change of density with temperature). We should say that

$$m = \frac{6}{QL} \text{ gives } \frac{dm}{m} = -\frac{dQ}{Q} - \frac{dL}{L}$$

$$\text{and from } Q = \frac{4}{dh\rho} \qquad \frac{dQ}{Q} = -\frac{dh}{h} - \frac{d\rho}{\rho}$$

$$\text{whence} \qquad \frac{dm}{m} = \frac{dh}{h} + \frac{d\rho}{\rho} - \frac{dL}{L}$$

or since $\frac{dm}{m}$, being a coefficient of expansion, $= -\frac{d\rho}{\rho}$,

$2\frac{dm}{m} = \frac{dh}{h} - \frac{dL}{L}$, which fits Waterston's data much better.)

"The product mQL has the same constant value for all liquids at any temperature, hence this relation—assuming it to be proven—enables us to compute the latent heat from the capillarity and vice versa."

I have quoted from Waterston's paper in detail because, as Lord Rayleigh remarked with reference to the famous paper by Waterston on "The Physics of Media that are composed of free and perfectly elastic molecules in a state of motion" which was refused publication by the Royal Society in 1846 and only published by the Society on Lord Rayleigh's advice in 1892. "Waterston's views upon physics and upon chemistry also were much in advance of those generally held at the time . . . "

In recent years the ideas of Waterston upon the connection between latent heat and evaporation have been worked upon by others without reference being made in any instances, as far as I have noticed, to Waterston's prior calculations. Thus Hammick in Phil. Mag 38, p. 240, August, 1919, following Matthews (Jour. Phys. Chem., 1916, XX, 555) obtains

$$\frac{6TV}{d}=L_1$$

where T = surface tension (energy is stated but tension is taken).

d = molecular diameter.

V = volume of one gramme-molecule.

L_1 = internal latent heat of vaporisation of the gramme molecule.

The ratio $\frac{L_1}{V}$ is the same whatever quantity of liquid be taken.

If, following Waterston, we make in the mass of a cubic inch we get

$$\frac{L_1}{V}=\frac{L_1\rho}{1}$$

and since d = m, Hammick's equation

$$\frac{6TV}{d}=L_1 \text{ becomes } \frac{6T}{m}=L_1\rho$$

$$\text{or } m=\frac{6T}{L_1\rho}=\frac{6}{QL_1}$$

which is Waterston's relation, with the exception that Waterston does not discriminate between the internal and total latent heat.

Hammick gives a long table comprising 29 substances and says the relationship $\frac{TV}{d}=\frac{L_1}{6}$ fits the facts remarkably well. He expresses these quantities in calories. Rudorf in Phil. Mag., Vol. 39, p. 238, points out that for argon which is quoted by Hammick the data employed were incorrect and instead of getting $\frac{TV}{d}=226$ and $\frac{L_1}{6}=214$, Rudorf gets $\frac{TV}{d}=302$ and $\frac{L_1}{6}=240$. As Rudorf adds "the agreement between 302 and 240 can hardly be considered good."

The agreement between the values for water are even worse; $TV/d=1133$, $L_1/6=1699$. A point that crops up here is whether the surface tension should be taken or the surface energy. In defining T he states it to be the surface energy in ergs per sq. cm. but in the table the surface tension in dynes per cm. is quoted. Now the surface tension of water at 0°C. is about 75.6 dynes per cm. but the surface energy equals 115.7 ergs per cm^2, and if we take the latter value, we get for TV/d not 1133 but 1735 which is not so very far off 1699.

In Phil. Mag. Vol., 39, Jan. 1920, Hammick carried on his work still further and obtains many interesting comparisons. Hammick treats of plane surfaces just as Waterston did.

Mr. Wilson Taylor in a paper published in Phil. Mag., Vol. 41, 1921, applies the formulæ to spheres. Starting with a gram-molecule of liquid spheres of the same size he finds how small they must be at the start in order that the total energy yielded up by the shrinkage of the surfaces as they condense into a single sphere may be equal to the internal latent heat of vaporisation. From the original size he deduces the number

$$n=\left(\frac{L}{T}\right)^3\frac{m\rho^2}{36\pi}$$

Where L=latent heat of vaporisation per gram at θ°A.
T=the tension of the envelope at θ°A.
m=the molecular weight.
ρ=the density of the liquid at θ°A.

Taylor suspects that n should be Avogardro's number and selecting water as a test substance, by a happy selection of the internal latent heat of vaporisation at 373°A, viz 498, the density of water at 277°A viz. 1, and an extrapolated value of the surface tension of water at 0°A viz. 133.6, he arrives at $n=6.05\times10^{23}$ which is very near the accepted value of the number of molecules per gram molecule. That his formula cannot be true is evidenced by the values of n he calculates for a number of other substances. Thus for mercury he gets 0.21×10^{23} and for methyl alcohol 12.68×10^{23}.

Anyone who looks up the tables of surface tensions will see how varied are the results obtained for T by different experimenters and it seems going beyond the bounds of reason to deduce by extrapolation a value of T for a solid, "ice," at a temperature 273° below the temperatures at which T has been measured for the liquid, water.

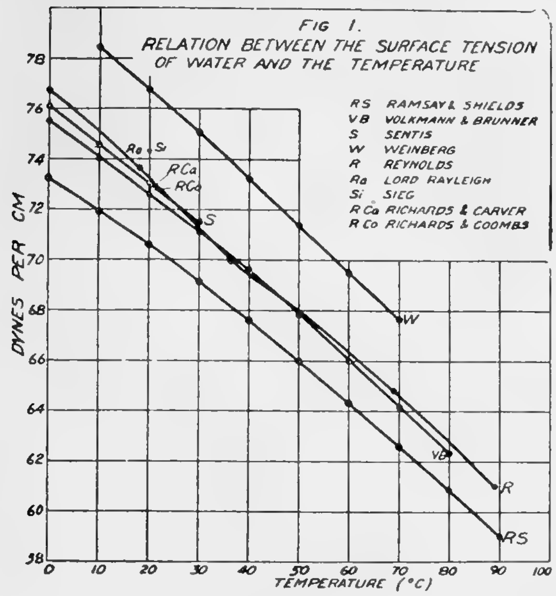


Fig. 1 illustrates the results obtained by different observers for the surface tension of water over the range 0° to 100°C. The values differ widely, not only in absolute magnitude but in their temperature coefficients.[1]

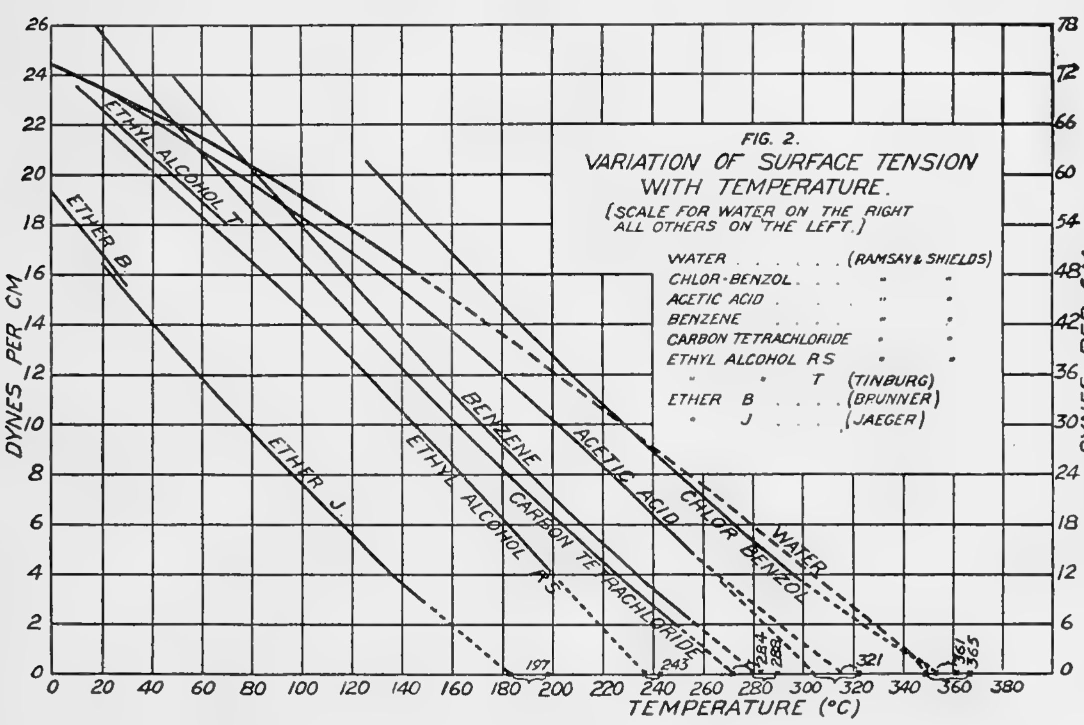


Fig. 2 shows in the same way for a number of liquids the variation of surface tension over a wide range of temperature.[2] I have

[1] Data from Landolt and Bornstein's Tables and elsewhere.

[2] Weinstein's data for water gives a curve about .6 higher than Ramsay and Shields' curve in Fig. 1. In Fig. 2, the curve marked Ether, J. should be Ether, Ramsay and Shields.

produced the curves down to the axis of zero surface tension. For each liquid the intersection occurs not far below the critical temperature, but it will be seen that the curves are far from straight and that the well-known linear equaton $T_\theta = k\ (\theta_c - \theta_1 - \theta)$ where θ_1 is about five or six degrees, is only an approximation holding for a small range of temperature below the critical temperature.

Again it seems to me that surface energy should be used and not surface tension. It is well-known that when a film contracts isothermally it does mechanical work given by $T \times$ (decrease of area) and also gives out heat to the surroundings. The formula connecting T, the surface tension, with S, the surface energy, is the well-known free energy equation

$$T = S + \theta \frac{dT}{d\theta}$$

where θ is the temperature. The temperature coefficient of T is not constant. This alone would make Taylor's extrapolated value of T at 0°A rather wide of the mark.

For water at 273°A, $\frac{dT}{d\theta}$ is about .147 in C.G.S. units so that S at 273°A $= 75.6 + 40.1 = 115.7$ ergs per sq. cm.

Putting in Taylor's equation the values of the physical constants of water at 273°A we get

$$n = \left(\frac{564 \times 4.18 \times 10^7}{116}\right)^3 \times \frac{18 \times 1^2}{36\pi}$$

$$= 1.34 \times 10^{24}$$

Supposing we take the physical constants at 373°A;

$$S_{373} = 58.8 + 373 \times .185 = 127.8 \text{ ergs per sq. cm.}$$

$$\therefore n = \left(\frac{498 \times 4.18 \times 10^7}{128}\right)^3 \times \frac{18 \times .96^2}{36\pi}$$

$$= 5.89 \times 10^{23}$$

The variation shows that although the value of n will be of the right order the calculation is useless for getting an accurate value of Avogadro's number. The formula does not include all the facts, the assumptions are too approximate[3] and the data are not suffi-

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[3] For example, our knowledge of the value of T for spheres of just over molecular size is very vague and it is the shrinkage of surface in the early stages which apparently liberates the most energy (loc. cit. p. 885). Also the vapour pressure relations of small drops, involving among other things the change of latent heat of vaporisation with change of curvature, would have to be considered.

ciently known to make it worth while bothering with the method as a means of calculating Avogadro's number.

Again using his formulæ for the potential surface energy Taylor deduces that if d is the diameter of a molecule

$$d = \left(\frac{6m}{\pi\rho N}\right)^{1/3}$$

but this can be obtained more simply from the mass equation

$$N\left(\frac{\pi d^3}{6}\right)\rho = m$$

without bringing in surface tension at all.

I find it difficult to follow Taylor's reasoning when he says:

"The result obtained above (i.e. the deduction of $N = 6.05 \times 10^{23}$) would seem to furnish an argument in favour of the view that the properties of surface tension can be considered as not depending upon the mutual attractions of molecules. For if the free molecule has about it this elastic envelope it is plain that the envelope cannot be material at all. It is simply a force and nothing more."

Again, in Nature, Jan. 5, 1922, he says that the coalescence of gaseous and liquid spheres is not due to molecular attraction. "The alternative is that it is an elemental force acting, not in lines, but over areas."

Also in the *Physical Review*, April, 1922, he says "Cohesion and adhesion are simply surface tension forces which exist about all free masses, molecular or larger, attaching themselves to each other in the periphery of the contact area and binding the two masses together in one enveloping surface tension force."

The connection between forces and binding envelopes is vague, and forces acting not in lines are beyond my comprehension.

It is interesting to see how nearly S remains constant as the temperature is changed. From

$$T = S + \theta \frac{dT}{d\theta}$$

$$\frac{dT}{d\theta} = \frac{dS}{d\theta} + \frac{dT}{d\theta} + \theta \frac{d^2T}{d\theta^2}$$

$$\therefore \frac{dS}{d\theta} = -\theta \frac{d^2T}{d\theta^2}$$

If $\frac{dT}{d\theta}$ is constant $\frac{d^2T}{d\theta^2} = o$ and $\therefore$ S does not vary with temperature.

The curves in Fig. 1 show that $\frac{dT}{d\theta}$ has been found by some experimenters to be constant, by others to change, hence it is likely that S also changes.

It is surprising that Lord Rayleigh in all his work on surface forces apparently does not develop Waterston's theories. He works more on the theories of Young, Laplace and Dupré, using the idea of Intrinsic Pressure. An elementary treatment of this part of the subject is given in Poynting and Thomson's Properties of Matter, although even these writers apparently make an error (See pp. 174, 175, 1902 edition). Following up Laplace's conception of the internal pressure they equate the latent heat of evaporation of unit volume of the liquid to the intrinsic pressure. Thus in the case of water at 20°C. they get

$$K = 550 \times 4.2 \times 10^7 \text{ dynes per sq. cm.}$$
$$= 23100 \text{ atmospheres.}$$

while their own text on p. 175 show that to bring unit volume from the interior to the surface necessitates work equal to K and an equal amount is required to tear the unit volume off the surface layers and to disintegrate the films into a gas. This would make $K = 11500$ atmospheres a value agreeing much better with that obtained by Van der Waals from the term $\frac{a}{v^2}$ of his celebrated equation. Young in 1805 got 23,000 atmospheres and apparently Lord Rayleigh (Phil. Mag. XXX, 1890, Collected Works, Vol. III., p. 423) agrees in the method, for he says "The view (viz. $K = L$ per unit volume) appears to be substantially sound" and by direct equation as above gets for water, $K = 25000$ atmospheres.

University of Toronto.

*The Partial Oxidation of Methane in Natural Gas**

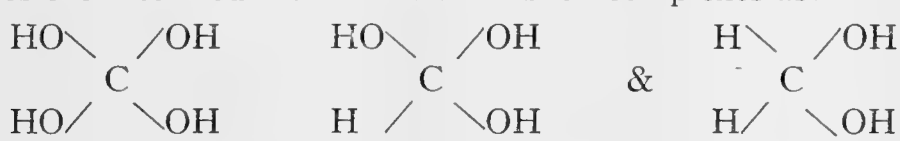
R. T. ELWORTHY, B.Sc., A.I.C.

Although many suggestions have been put forward and many patents have been taken out for the production of oxidation products of methane from natural gas, the possibilities of partial oxidation have received little attention from the scientific standpoint, judged from the lack of information in the literature. The negative character of so much of the work that is known to have been carried out may account for this. The following paper describes some experiments performed on this subject.

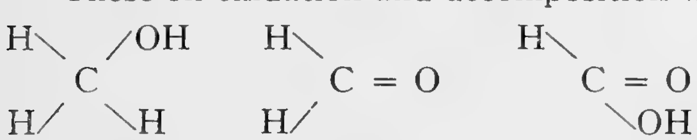
The Combustion of Methane

The chief theories of the mechanism of combustion of methane are almost all based on the hypothesis that the ultimate decomposition into carbon dioxide and water is preceded by the formation of complex hydroxylated molecules, which, in the course of the reaction, break down in stages. The fact that the presence of at least a trace of moisture is essential for combustion to take place is thereby explained.

E. F. Armstrong,[1] one of the chief exponents of this theory, assumes the intermediate formation of such complexes as:



These on oxidation and decomposition would yield:



before finally giving CO_2 and H_2O.

He found experimental evidence for his theories in the work of Bone and Wheeler,[2] who showed formaldehyde to be one of the products of the reaction between methane and oxygen when these gases were circulated over boro-silicate glass at temperatures between 450° and 500°C. They proved that formaldehyde was not formed by the combination of carbon monoxide and hydrogen under the conditions employed but that these substances resulted rather from

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[1] Jour. Chem. Soc. Trans. 83, 1088, 1903.

[2] Jour. Chem. Soc. Trans. 83, 1074, 1903.

its decomposition. Many workers[3] on the limits of inflammability of hydrocarbons in air have noted the formation of aldehydic odours under certain conditions. That formaldehyde is formed in lighting a natural gas flame in a cold furnace is frequently observed.

It should be possible, therefore, to find the conditions under which some of the more stable intermediate products can be prevented from further decomposition and isolated.

The following methods which might have commercial application were tried out:

1. Passage of natural gas and oxygen over heated catalysts.
2. Oxidation by ozone.
3. Reaction between methane and carbon dioxide.

As yet no work has been done on oxidation of methane in solvents.

Method I—*The Passage of Methane and Oxygen over Catalysts.*

This method is the subject of several patents: Blackmore in U.S. Pat. 774,824 used iron oxide as catalyst. Unruh U.S. Pat. 891,753 proposed the use of tan bark. D.R.P. 286,731 specified metals or metallic couples, and D.R.P. 207,380, 1918, protects the use of croceo-cobalt nitrate.

The chief factors which enter into the reaction are: (1) Nature and form of catalyst, (II) ratio of methane to oxygen, (III) temperature, (IV) time of contact, (V) effect of water vapour and impurities in the gases.

Experimental

The train of apparatus was usually:

purified natural gas — flow gauge ╲ mixing chamber ╱ gas meter—flow gauge
Oxygen—flow gauge ╱
—Drying tower —catalyst chamber—absorption train—gasometer.

Catalyst chamber

The catalyst chamber used in most experiments, shown in Fig. 1, consisted of two concentric tubes of pyrex glass, the outer one sealed at one end. The catalyst was packed for certain length in the centre of the inner tube, which was supported in the outer tube by a rubber cork.

[3]Burgess and Wheeler, Jour. Chem. Soc. 99, 2020, 1911.

The incoming gas, entering at the top of the outer tube, was preheated by flowing down the annular space. It then passed up the inner tube, through the catalyst and out through a side tube near the top. The gases were then bubbled through wash bottles containing water to take out the soluble oxidation products.

This catalyst chamber was supported vertically in an electric furnace, thermostatically controlled. The temperature of the chamber was recorded by a copper-constatin thermocouple imbedded in the catalyst.

The second type of chamber used in some of the later experiments was made of pyrex glass, shaped as shown in Fig. 2, the flanges being held together by clips. The catalyst, made up into a paste with water and asbestos, was coated on a flat spiral, iron-coated, insulated heating element and then baked. The leads of the heating element passed out through a rubber cork at one end of the cylinder and the temperature could be maintained at any desired point very readily by means of resistances. A hard glass tube reaching into the centre of the spiral served as a sheath for the thermocouple recording the catalyst temperature. The gases entered through a second side tube and after passing through the catalyst were scrubbed.

The natural gas used in all the experiments was supplied by the Dominion Natural Gas Co. from a well at Simcoe, Ont.

The analysis of a representative sample gave:

Methane	80.3	per cent.
Ethane	7.6	" "
Carbon dioxide	0.3	" "
Oxygen	Nil	
Nitrogen	11.8	" "
Hydrogen sulphide	Nil	

It would have been preferable to have used pure methane, but the lack of liquid air prevented the preparation of methane by liquefaction and distillation from this gas and the quantities required for the work were too large to make the preparation of methane by the recognized laboratory methods feasible.

The gas was purified when necessary by passage through potash solution and strong sulphuric acid.

Complete gas analyses were made in an improved form of Burrell apparatus. An Orsat apparatus was used for the many partial estimations.

Catalysts

The chief catalysts used were magnetite, iron oxide, copper oxide, silver oxide, thorium oxide, platinum, cobalt oxide, vanadium oxide, uranium oxide and borosilicate glass. These catalysts were usually prepared by the ignition of the nitrates and were mixed with asbestos, pumice, or activated charcoal as carriers.

Examination of the Products of the Reaction

The gases issuing from the catalyst chamber were passed through a series of wash bottles containing water, which took out any formaldehyde or methyl alcohol formed by the reaction. Tests proved that these products were retained by the water even though the gases were passing at a rapid speed.

After the removal of the soluble products the gases were collected and always analysed for carbon dioxide and oxygen and sometimes for methane and ethane.

The wash waters were tested qualitatively for formaldehyde with Schiffs reagent, and by the resorcine test.[4] The presence of methyl alcohol was detected by observing any increased quantity of formaldehyde formed when the solution was oxidized by a hot copper wire spiral. The solutions were examined quantitatively by first estimating the formaldehyde colorimetrically in one portion and in another by oxidizing the methyl alcohol with alkaline permanganate, destroying excess of permanganate with oxalic acid and then determining the total formaldehyde according to Elvove's method.[5] By difference the methyl alcohol was obtained. Where these substances were present in larger quantity the formaldehyde was estimated by Lockemann and Cronen's method[6], which consists in titrating the acid set free when formaldehyde is added to a measured volume of a normal solution of hydroxylamine hydrochloride. The amount of alkaline permanganate required for oxidation of both formaldehyde and methyl alcohol was found and the methyl alcohol calculated from the known amount of aldehyde present.

Of the many methods in the literature, most of which were tested in the course of the work, these gave the most reliable and rapid results.

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[4]Muliken, Identification of Pure Organic Compounds, Vol. 1, p. 24.

[5]Elvove, Jour. Ind. Eng. Chem. 9, 295, 1917.

[6]Lockemann and Cronen, Zeit. Anal. Chem. 54, 11-26, 1915.

Results

The first series of experiments was made by passing natural gas over magnetite, at various temperatures between 150° and 400°C.

The results were all negative. Magnetite can hardly be regarded as a catalyst for it takes part in the reaction. Iron oxide, prepared by igniting ferric hydroxide and copper oxide on asbestos, were similarly tried out. In the latter experiments oxygen was mixed with the natural gas in the ratio of 1:2 and 1:1. The temperature in various experiments ranged from 150° to 380°C. and the volume of natural gas passed through one litre of catalyst in one hour, a relation known as the "space velocity," varied from 11 to 55. Faint traces of formaldehyde were detected at 380° with copper oxide.

A further series of experiments was then carried out with this catalyst at higher temperatures in which the ratio of gas to oxygen was varied, the total flow rate being constant at 0.1 litre per minute.

The results are given in the following table:

Catalyist—Copper Oxide on Asbestos

Temp. Catalyst °C.	Ratio CH_4:O_2	Flow rate mixture litres per minute	Space velocity L. per L. catalyst per hour	Gas Analyses						
				Initial Gas			Final Gas			
				CH_4	O_2	CO_2	CH_4	O_2	CO_2	CO
410	3:1	0.10	187	78.5	20.8	0.2	....	1.8	12.0	...
410	5:1	0.10	210	78.5	14.4	0.4	....	1.8	6.2	...
500	3:1	0.10	187	74.6	25.1	0.3	....	4.5	1.3	...
500	3:1	0.10	187	74.2	24.7	0.7	81.6	1.4	16.8	0.2
500	2:1	0.10	165	65.0	30.3	0.6	....	4.2	17.6	0.2
500	5:1	0.10	210	78 4	17.4	0.6	....	2.3	16.3	...
500	9:1	0.10	225	85.2	9.4	0.6	....	1.4	2.8	...

Formaldehyde was detected in each case but never in sufficient quantity for a reliable quantitative estimation, though such determinations showed relatively larger amounts in the last four experiments of the series than in the earlier ones.

Assuming a conversion of only 1 per cent. methane to formaldehyde, at least 5 mgm. aldehyde should have been present according to the quantity of gas put through, yet not one-tenth of this amount was found at the most. Methyl alcohol was never detected.

The experiments show that formaldehyde is not formed at a lower catalyst temperature than 400° yet the work of Bone and Smith[7] on the decomposition of formaldehyde proves that at this

[7]Jour. Chem. Soc. 910, 1905.

temperature some decomposition takes place into carbon monoxide and hydrogen. The decomposition is complete at 700°. This fact probably accounts for the presence of carbon monoxide in the latter experiments of this series and for the poor yields obtained throughout.

A further series of experiments was carried out using silver oxide, thorium oxide, platinum, borosilicate glass, vanadium oxide and uranium oxide, at temperatures from 250° to 500°, with varied mixtures of methane and oxygen, and space velocities ranging from 150 to 600. The same general results were obtained as for copper oxide and traces of formaldehyde were detected at temperatures of 400° and above. It is not thought worth while including similar tabular statements of these experiments.

Several qualitative tests were made on the formation of formaldehyde when a natural flame impinged on a cooled surface. One arrangement was to have a flame, two inches long, playing on the circumference of a large iron fly wheel, slowly rotated. Traces of formaldehyde were detected in the water resulting from combustion which had condensed on the cold surface. A similar flame was allowed to play on a large cake of ice and the water formed then examined. This gave negative results.

Conclusion

These experiments prove that slight traces of formaldehyde can be formed by the passage of natural gas and oxygen over metallic oxides, but due to the greater liability of the formaldehyde to decomposition at the temperatures necessary for its formation it is improbable that this method could be developed as a means of preparation of the aldehyde.

Method II—*Oxidation with Ozone*

Several observers have studied the effects of ozone on the saturated hydrocarbons, especially M. Otto[8] in 1898 and J. Drugman[9] in 1906. When methane and ozonized oxygen were mixed at 15° and at 100° some formaldehyde and higher oxidation products resulted, but the quantity was small even though 200 litres of methane were used. Hauser and Herzfeld[10] state that small amounts of methane are quantitatively oxidised to formaldehyde by ozone.

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[8]M. Ottlo Ann. Chim. Phys. (Ser. 7) 13, 109, 1898.
[9]J. Drugman, Jour. Chem. Soc. Trans. 89, 939, 1906.
[10]Berichte, 45, 3575, 1912.

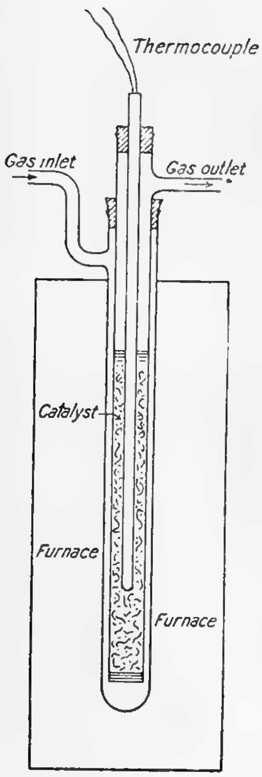

Fig. 1.

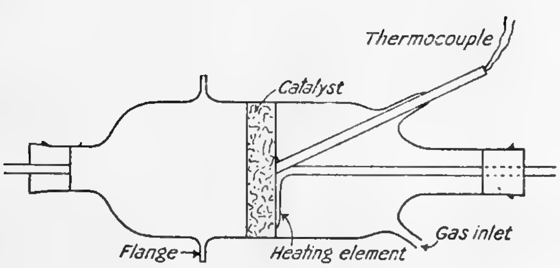

Fig. 2.

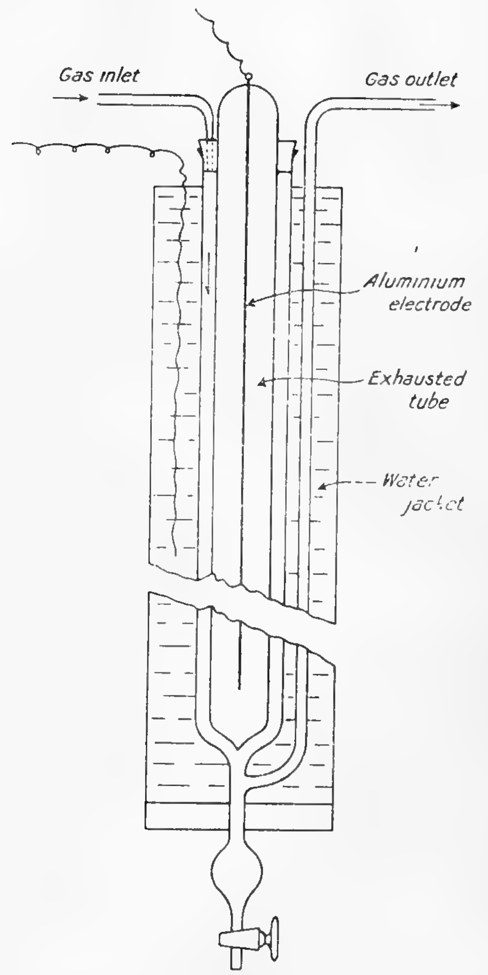

Fig 3

Experimental

The ozonizer consisted of two concentric glass tubes, as shown in Fig. 3, with the volume of the annular space 25 c.cs. The inner glass tube, sealed at either end and exhausted to 1 mm. pressure, served as one electrode, the current being led in by an aluminium wire sealed in. The annular space was closed at the top by a rubber stopper, painted with shellac, and at the lower end the outer tube was drawn off to a 3/8 in. diam. tube, closed by a stop cock. The ozonized gas passed out by a side tube. The ozonizer was surrounded by a water jacket to keep down the temperature; cold, acidulated water passed through it, this liquid serving also as the second electrode, connected to the induction coil by a wire dipping in it. A 12 in. spark coil was used as a transformer with 10 amps. 110 volts, 60 cycle A.C. current passing through the primary. Conditions were maintained so that with a flow of well dried oxygen of 0.1 litre per min. 60-70 gm. ozone per cubic metre of oxygen was formed, approximately equivalent to 3 per cent. by volume.

The ozonized oxygen was led into a chamber, kept at any desired temperature in which it was mixed with natural gas. The mixed gases were passed through a condenser and wash bottles to a gasometer. All connections were made with ground glass joints or sleeves as ozone rapidly attacks rubber.

A number of experiments were made in which the proportions of gas and oxygen were varied and the temperature of the reaction chamber kept at 21°C. or at 100°C. Other experiments were carried out, using activated charcoal and silver as catalysts. Sufficient gas (10-20 litres) was passed to give at least 10 mgm. of formaldehyde or methyl alcohol, assuming only 1 per cent. of the methane present being oxidized, yet neither of these substance could be detected in any of the experiments.

This arrangement was then changed so that natural gas and oxygen were mixed in the ratio of 2:1 and the mixture itself passed through the ozonizer. After being subject to the action of the silent discharge the gases were led through a series of wash bottles containing water and thence to a gasometer.

Several experiments were carried out in which the flow rate of the mixed gases was 0.35 litre per min. The "space velocity" or litres gases passed through one litre volume of ozonizer in one hour was therefore 840.

In each case a viscous liquid formed on the sides of the ozoniser and several ccs. were collected and examined. This liquid was found to contain polymerized aldehydes and resins, methyl alcohol, formaldehyde and formic acid. The wash waters gave strong reactions for formaldehyde but no quantitative examination was made.

Several explosions occurred, however, in the course of the experiments and the form of the apparatus was not quite satisfactory. It seemed one of the most promising lines of attack and further experiments should be made, using much greater space velocities, different mixtures of gas and oxygen, and better cooling and safety devices.

Method III—*The Reaction Between Methane and Carbon Dioxide*

It was thought that by passing natural gas and carbon dioxide over heated metals the oxygen formed at least in small amounts by the decomposition of the carbon dioxide might react with the methane or the fugitive $:CH_2$ and $:CH$ groups, which are perhaps momentarily existent with the formation of partial oxidation products.

The work of Bone and Coward[11] on the decomposition of hydrocarbons by heat showed that methane is the most stable of the simple hydrocarbon gases and carbon and hydrogen are only formed when this gas is heated to 900-1000°. With metallic oxides and substances affording considerable surface decomposition is much greater, according to Slater.[12]

The equilibrium between carbon dioxide, carbon monoxide and carbon has been studied by Rhead[13] and Wheeler and by Boudouard[14] with the following results at atmospheric pressure.

Temp. C.	450	500	600	700	800	900	100
Percentage $C0_2$	95	95	97	42	7	2.22	0.59
$\frac{P\ Co_2}{P\ C0}$	49.0	19.0	3.35	0.72	0.075	0.0227	0.000593

In mixtures of 40-60 per cent. $C0_2$ with 60-40 per cent. the partial pressure of the $C0_2$ will be one-third to one-half of an atmosphere tending to greater dissociation than given in the table. The presence of this amount of $C0_2$ will also check the tendency for the formation of the complete oxidation products of methane.

Experimental

The arrangement of the apparatus used in the experiments is shown in Fig. 4.

[11]Jour. Chem. Soc. Trans. 93, 1197-1225, 1908.
[12]Ibid, 109, 160-164, 1916.
[13]Jour. Chem. Soc. Trans. 2178, 1910, and 99, 1141, 1911.
[14]Ann. Chim. Phys., Series 7, 24, 5, 1901.

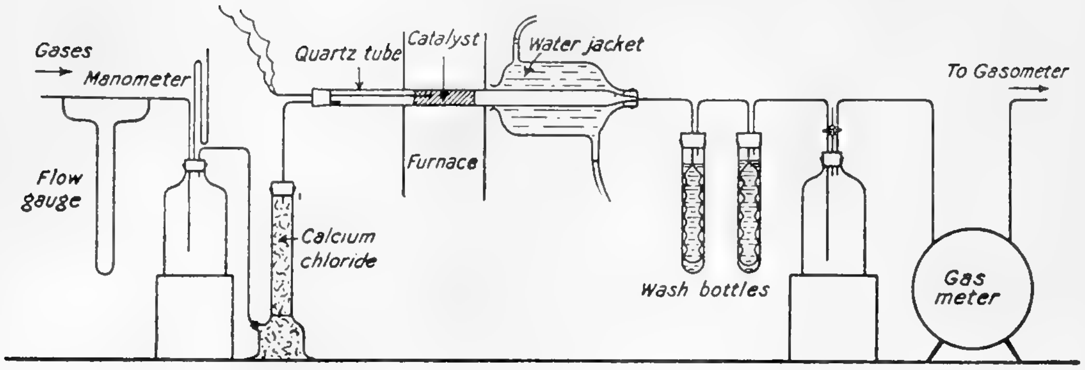

Fig. 4

The mixture of natural gas and carbon dioxide was passed through a transparent quartz tube containing the catalyst. The catalyst zone of the tube was heated by three blast lamps. A water jacket was fitted over the rear portion of the tube with the object of quickly cooling the gases, leaving the catalyst zone and preventing further oxidation.

In the earlier experiments natural gas containing 80 per cent. of methane (including ethane) was mixed with carbon dioxide in a gasometer. In the later series the gases issued from cylinders and after passing through flow meters were mixed in a large bottle. After being dried the gas mixture flowed at a pressure of 5 cms. of mercury over the catalyst, through the cooling zone and through wash bottles containing water into a second gasometer. The temperature of the catalyst was given by a platinum, platinum-rhodium thermocouple. Samples for analysis were collected at intervals of the initial mixture and of the final product. The wash waters were tested for formaldehyde and methyl alcohol, qualitatively by Schiffs reagent and quantitatively by the colorimetric method.

Copper, in the form of discs of fine mesh gauze packed closely together for a length of 3 cms., was the first metal tried. A series of runs was carried out, varying the temperature between 500°C and 800°C. and using different flow rates.

In another series the effect of platinized asbestos was studied and in a third the catalyst was reduced silver on pumice. Each of these substances was packed into the quartz tube so that the volume of catalyst space was 6 ccs.

Results

The following table summarizes the data obtained in the chief experiments:

Temp. Catalyst °C.	Approx. ratio CH_4:CO_2	Rate of flow L. per min.	Space velocity L. per L. catalyst per hour	Gas analyses						Formaldehyde in wash waters mgm.
				Initial			Final			
				CH_4	CO_2	O_2	CH_4	CO_2	O_2	
Copper gauze										
450	3:1	0.2	2150	65.0	21.6	2.4	...	22.1	0.7	negative
800	2:1	0.4	4300	60.0	29.0	1.0	...	26.6	1.4	positive
820	4:1	0.2	2150	74.6	16.2	3.8	...	8.8	7.1	positive
880	5:1	0.4	4300	....	14.6	1.6	...	31.0	4.0*	0.5
Platinum asbestos										
650	4:1	0.5	5000	58.0	31.4	0.4	...	23.8	2.0	negative
680	5:2	0.7	7000	....	18.6	0.9	...	18.5	0.8	negative
760	5:1	0.7	7000	78.7	13.9	1.6	...	16.6	2.2	1.26
770	2.5:1	0.35	3500	75.0	21.4	3.3	...	20.0	1.0	1.66
Silver asbestos										
750	5:2	0.7	7000	69.7	19.8	2.8	71.1	22.0	2.6	1.20

* Gases contaminated by air leak.

The results were disappointing in that although formaldehyde was formed with either metal at 700°C. and over the amounts were insignificant.

The small percentages of oxygen present in the initial gas may partially account for the oxidation though it is evident from the analyses that oxygen was also formed in the reaction, the final percentages being greater than the initial.

At least 12 litres of methane were used in each experiment and assuming 1 per cent. of the methane partially ozidized, 10 mgm. formaldehyde should have been formed. Yet only one-hundredth of that amount was found.

The experiments were, therefore, discontinued.

Summary

Three possible methods of obtaining partial oxidation products of methane from natural gas have been described.

(1) Oxidation of methane by passage of natural gas and oxygen over certain catalysts.

(2) Oxidation by the action of the silent discharge on mixtures of natural gas and oxygen.

(3) The reaction between methane and carbon dioxide.

Traces of formaldehyde were found under certain conditions in each method but oxidation by ozone is the only one which might repay further study.

I am greatly indebted to the valuable review of the literature on methane and its properties by M. Malisoff and G. Egloff[15] for many suggestions and references.

Mr. Westman, M.A., and Mr. R. G. Offord have rendered much assistance in the course of the work in making many of the gas analyses and in carrying out many of the experiments.

[15]Jour. Phys. Chem. 22, 529-575, 1918.

*The Formation of Unsaturated Hydrocarbons from Natural Gas**

By R. T. ELWORTHY, B.Sc.

In a book[1] on "Rubber, Its Chemistry and Synthesis," Dubosc and DeBoistesselin refer briefly to a method of preparing ethylene and propylene by passing methane over carbon impregnated with copper oxide at 400-450°C. The proportions obtained were approximately:

Ethylene	36 per cent.
Propylene	42 " "
Higher olefins and hydrogen	21 " "

but no figures are given showing what fraction of the methane was changed.

If a considerable percentage of ethylene could be formed, in view of the developments in the industrial use of this gas, this reaction might be of importance.

The following paper outlines some experiments carried out to see what yields of unsaturated hydrocarbons could be obtained in this way.

Many observers have studied the decomposition of the simple hydrocarbons by heat. Berthelot, as a result of exhaustive work, claimed that acetylene was always the ultimate product of decomposition. V. B. Lewes, working chiefly on ethylene, agreed that this gas is primarily resolved by heat into methane and acetylene. Bone and Coward,[2] however, disproved Berthelot's theories. They showed that methane is the most stable of the lower hydrocarbons decomposing slightly at 800°C., but rapidly at 1100°C., into its elements hydrogen and carbon, and that the effect of heat on ethane and ethylene is a loosening of hydrogen with the fugitive formation of $:CH_2$ and $:CH$. These radicles eventually combine giving ethylene, acetylene or methane if much hydrogen is present or they may be decomposed into their elements. Hollings and Cobb[3], studying the effect of heat on various gases in contact with coke, confirmed these results, finding that ethane decomposed slowly at 800°C., forming ethylene and methane, and that ethylene was broken down rapidly at 1100°C. giving methane and hydrogen. From these statements it

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*Published by permission of the Director, Mines Branch.

[1]Published by C. Griffin and Co., London, p. 253.

[2]Jour. Chem. Soc. Trans. 93, 1197, 1908.

[3]Jour. Inst. Gas Engineers, 1914.

seems unlikely that much ethylene could be obtained in this way. It is also probable that any ethylene found results from the decomposition of ethane present rather than from the reaction of methane or its decomposition products with carbon. The best conditions should be: (i) the absence of hydrogen, (ii) temperature below 800°C. It is recognized that in the carbonization of coal[4] the highest yields of olefines are found at retort temperatures of 400-500°C.

Again methane and acetylene heated at high pressures to 200-350°C. combine to form propylene, using suitable catalysts. Therefore, if the natural gas used contained considerable quantities of ethane, acetylene formed by its decomposition might react with methane and so produce propylene.

Experimental

The arrangement of apparatus was usually:

natural gas from cylinder — mixing chamber — flow gauge — heated quartz tube containing catalyst — train of absorption bottles — gasometer.

In the first set of experiments a fused quartz tube 46 cm long. and 1.7 cm. diameter was used. This was replaced by a transparent quartz tube 1.2 cm. diameter. In the later experiments rapid cooling of the gases after issuing from the catalyst zone was obtained by fitting a copper condenser internally in the quartz tube, reaching almost to the catalyst.

The tube was heated in an electric combustion furnace and the temperature of the catalyst recorded by a platinum, platinum-rhodium thermocouple.

Catalyst

A mixture of pumice, carbon black and copper oxide in the ratio by weight of 1:1:5 was used as catalyst. The reduction of the copper oxide commenced at 400°C. and was complete at 500°C. and hence in the experiments over 500°C. the reaction was between finely divided copper, carbon, methane and ethane.

Analytical Control

The initial and final gases were analysed for carbon dioxide, oxygen, hydrogen, unsaturated hydrocarbons, methane and ethane in a modified Burrell gas analysis apparatus. Partial analyses were made in an Orsat apparatus.

[4]V. B. Lewes, "The Carbonization of Coal," pp. 112-134, 1917. Van Nostrand.

The exit gases were examined for acetylene by the delicate method of E. R. Weaver[5] which depends on the formation of a brilliant red colloidal solution of cuprous acetylide. As little as 0.03 per cent. acetylene could be detected, but none was ever found in the exit gases under the conditions used.

The volumetric bromine absorption method of determining ethylene was used to check the more rapid gas analysis method.

To obtain more information on the nature of the unsaturated hydrocarbons formed, the exit gases were led through two wash bottles containing bromine covered by a layer of water and finally through one containing bromine water. The three bottles were cooled to about 5°C.

Results

A number of experiments were carried out, trying different catalyst temperatures and various catalyst volumes and flow rates. It was evident, after the preliminary tests, that only small quantities of unsaturated hydrocarbons were present in the gases which had passed through the catalyst at 400-500°C., and that the best results would be obtained at about 800° as the following figures show:

Space velocity litres gas per litre catalyst space per hour
(*a*) 104 (*b*) 203 (*c*) 420

Temp. C.		400	500	600	700	800	900	970
Unsaturated	(*a*)	...	0.4	1.2	1.8	2.6	...	nil
hydrocarbons	(*b*)	0.4	0.6	1.0	1.4	2.2	2.0	...
in exit gas%	(*c*)	...	...	1.2	0.9	1.0	...	...

In the two following series complete analyses were made of the initial and exit gases:

Gas Analyses

Temp. °C.	Space velocity	Initial					Exit				
		CO_2	O_2	CH_4	C_2H_6	C_2H_4	CO_2	O_2	CH_4	C_2H_6	C_2H_4
450	3720	0.3	0.6	80.3	7.6	nil	1.2	1.6	84.2	5.9	nil
530	3660	0.6	2.1	79.4	7.1	nil	0.3	2.8	80.1	7.5	1.1
620	3800	0.3	9.0	82.3	4.1	nil	1.4	3.3	78.0	3.8	1.6
800	7320	0.6	2.1	79.4	7.1	nil	0.4	2.2	84.8	5.5	2.5
845	3570	0.2	2.2	77.4	6.2	nil	5.1	0.5	78.1	3.5	2.8
440	420	...	3.5	88.0	5.5	nil	1.2	4.8	....	...	0.3
540	"	"	"	"	"	"	0.8	0.6	83.2	8.6	0.4
650	"	"	"	"	"	"	0.2	0.3	84.2	7.4	0.4
750	"	"	"	"	"	"	0.2	...	90.0	2.6	1.6
850	"	"	"	"	"	"	...	0.4	.....	...	1.7

[5]Jour. Amer. Chem. Soc. 38, 352, 1916.

These figures confirm the preliminary results and the following conclusions may be drawn:

(I) The amount of unsaturated hydrocarbons formed is always small.

(II) The optimum temperature is about 800°C. and a high space velocity favours their formation.

(III) The ethylene formed probably results from the decomposition of ethane and not by any reaction between carbon and methane.

Use of the Centrifuge in Coagulation of Electrolytes

By E. F. BURTON, F.R.S.C. and J. E. CURRIE, B.A.

Presented by PROFESSOR BURTON

(Read May Meeting, 1922)

In the experiments on the coagulating power of electrolytes added to colloidal solutions, difficulty is always found in comparing the results of different workers; this circumstance is due essentially to the long interval of time which must often elapse before judgment can be passed on the coagulation. In the following paper are given quantitative results of the coagulation of arsenious sulphide sol by electrolytes, in which the centrifuge was employed to increase the rate of sedimentation after the addition of the electrolyte.

The Centrifuge

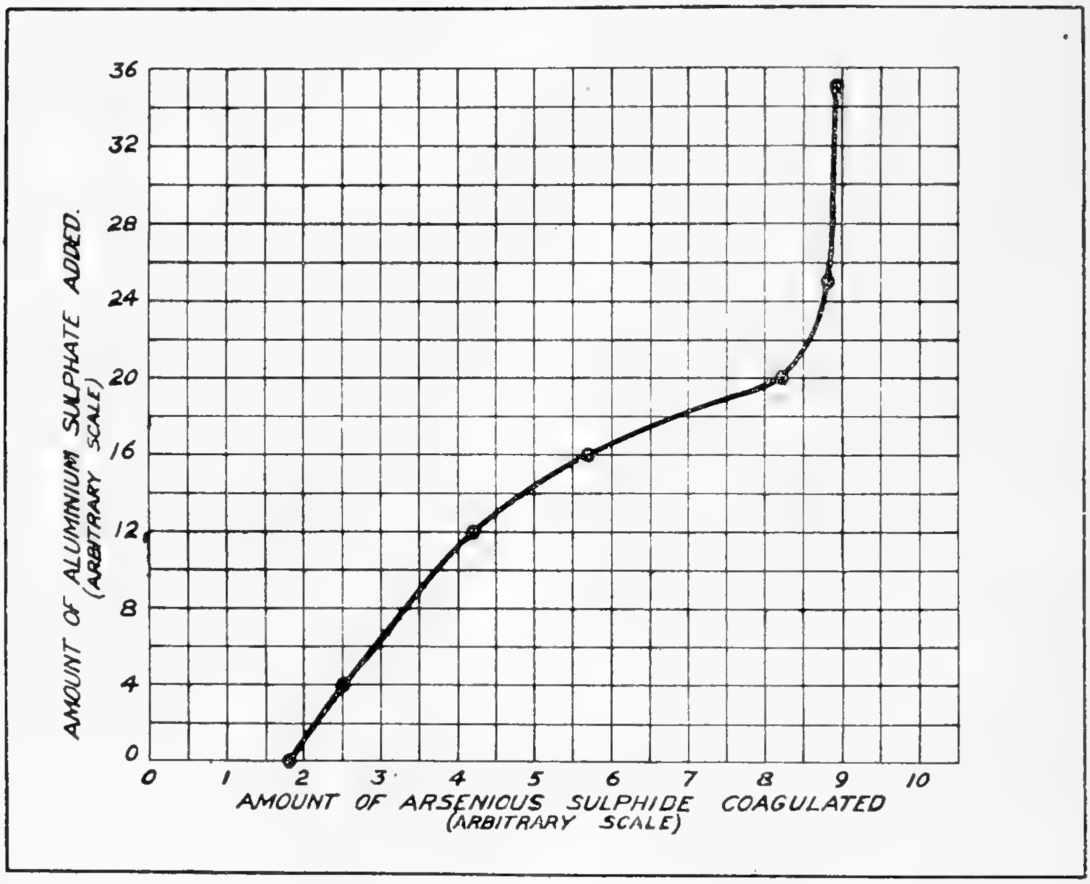
A Hearson electric centrifuge having a four-armed rotater was used and samples of the colloidal solution were held in glass tubes fitted into the four pivoted metal cups of the rotater. Graded amounts of the electrolyte were added to four different samples for each test and each set of four tubes were centrifuged for 20 minutes at 2750 R.P.M. At the end of this time the amount of solid deposited at the bottom of each tube was determined.

Preparation of the Solution

A colloidal solution of arsenious sulphide was used for these tests. About two and one-half litres of distilled water was heated and hydrogen sulphide gas bubbled through; when the temperature approached 90°C. about 30 grams of white oxide of arsenic was added slowly, with constant stirring of the solution. After some time the whole was cooled, pure hydrogen was bubbled through to free the sol from hydrogen sulphide, and the solution then filtered. This method gives a very stable sol of rather high sulphide content: analysis of the final solution gave 0.2342 grams of arsenious sulphide per 100 ccs. of sol.

Coagulation Experiments

The coagulant used was aluminium sulphate which has a trivalent metal ion and has, consequently, a powerful effect on arsenious sulphide sol, the particles of which are negatively charged. Varying small amounts of N/1000 aluminium sulphate were added, drop by drop from a standard burette, to 50 cc. samples of the sol and the whole well mixed. Each 50 cc. sample was divided into two equal parts, one part being centrifuged and the other put aside for observatioı of signs of coagulation in the ordinary way. Each set of 25 cc. samples to be specially treated was centrifuged for 20 minutes at 2750 R.P.M. and the amount of solid precipitate estimated, as follows: The arsenious sulphide precipitated was treated with nitric acid and ammonium persulphate which oxidise the arsenic to arsenic acid;



the arsenic was then precipitated as magnesium ammonium arsenate in presence of the phosphate; the arsenate was then dissolved in hydrochloric acid and to this solution potassium iodide was added in excess; iodine is freed quantitatively and estimated in the ordinary way by titrating with standard thiosulphate solution.

It was found that the centrifuging caused a slight deposit to come down even from the original solution; the amount of this deposit gradually increased with increasing amounts of aluminium sulphate added, but when the amount of the latter reached a certain limiting value the whole of the particles of the sol were coagulated.

In the accompanying table are given the details of the various samples; in the last column is given the amount of solid coagulum deposited from each sample.

No. of sample	No. of drops of aluminium sulphate added to 25 ccs. of colloidal solution	No. of grams of arsenious sulphide precipitated
1	0	0.0118
2	4	0.0165
3	12	0.0276
4	16	0.0375
5	20	0.0543
6	25	0.0579
7	35	0.0585

The supernatant liquid was quite clear in the case of the last sample and almost clear in the case of number 6. These results are illustrated in the figure from which it is seen that there is a very definite indication of the amount of aluminium necessary to produce coagulation.

These results are paralleled exactly by the behaviour of the second set of 25 c.c. samples which were left merely to the effect of gravitation. After the end of weeks the samples corresponding to numbers 5, 6 and 7 were completely coagulated, while the other samples showed decreasing degrees of sedimentation corresponding to the amount of aluminium sulphate added.

Determination of the Density of the Arsenious Sulphide Colloidal Particles

In order to make a calculation of the force acting upon the colloidal particles the density of the arsenious sulphide in the colloidal state was determined. The ordinary specific gravity bottle method was used and the temperature of all the samples was 23°C.

v = volume of bottle = 50.2024 ccs.

w_1 = weight of As_2S_3 in bottle full of solution = 0.1176 grms.

w_2 = weight of bottle full of colloidal solution = 50.4766 grms.

w_4 = weight of liquid medium in bottle full of solution 50.3590 grms.

d = density of liquid medium of solution = 1.0038, as found by experiment.

$\therefore \frac{w_4}{d}$ = volume of liquid medium in bottle full of solution =

$$\frac{50.3590}{1.0038}=50.1683 \text{ ccs.}$$

∴ Volume occupied by solid particles in bottle full of solution

$$v_1 = v - \frac{w_4}{d} = 50.2024 - 50.1683 = 0.0341 \text{ cc.}$$

∴ If x= density of the As_2S_3 particles

$$x = \frac{w_1}{v_1} = \frac{0.1176}{0.0341} = 3.45.$$

On looking up the mineral tables* of densities we find that arsenious sulphide is given as between 3.4 and 3.5.

This seems to be quite conclusive evidence that the ultimate structure of the particles is not of a loosely packed, spongy nature but is as compact as the sulphide in large masses.

Summary

A method is given by which the centrifuge may be made to hasten the coagulative action due to adding electrolytes to colloidal solutions, so that such determinations of coagulating power of electrolytes may be both hastened and standardized. Incidentally a determination of the density of the arsenious sulphide in colloidal solution is shown to be the same as that of the substance in large masses.

Department of Physics,
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* Dana: Textbook of Mineralogy, Ed. 1916, p. 282.

The Absorption and Effective Range of the β-Rays from Radium E

By MISS A. V. DOUGLAS, M.Sc.

Presented by J. A. GRAY, F.R.S.C.

(Read May Meeting, 1922)

Introduction

It was originally supposed that the β-rays emitted from some radioactive source, such as *Ra.E.*, were homogeneous, that is, of a definite velocity. When absorption curves were first taken it was natural to try a law of the exponential type, $I=I_0e^{-\mu x}$ where I_0 is the initial intensity of the radiation, I the intensity of the rays transmitted through an absorbing plate of thickness x, and μ the coefficient of absorption. The intensity is not directly measurable, but the assumption is made that it is proportional to the ionization which is produced in an electroscope. The experimental procedure is as follows:

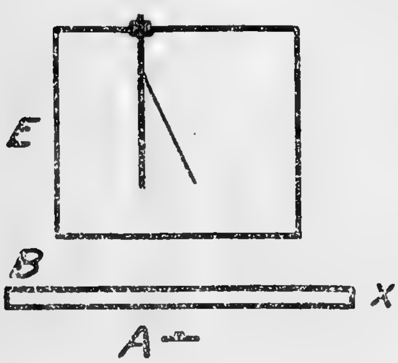

Fig. 1

The active material is placed at A and the ionization is measured by the rate of fall of the gold-leaf in the electroscope E (Fig. 1). The absorbing plate B, of thickness x, is placed in the position as shown, and the ionization as before. The ionization, and hence the intensity, is found to decrease as x is increased. To understand the nature of the absorption it is necessary to determine the relation between I and x.

From the equation given above, it follows that:

$$dI=-\mu I_0e^{-\mu x}\quad dx=-\mu\ I\ dx$$

$$\text{or } \frac{dI}{I}=-\mu\ dx.$$

Hence for equal increments of thickness dx the ratio $\frac{dI}{I}$ is constant.

A further relation is obtained thus: $\log I+\mu\, x=\log I_0$. Hence if log I be plotted against x a straight line curve should result.

Also if I_r, I_s, I_t, etc., represent the relative intensities of rays transmitted through thicknesses x_0, x_0+x^1, $x_0+2\ x^1$, etc., then the per cent. transmitted should be constant. That is $\frac{100\ I_s}{I_r}$, $\frac{100\ I_t}{I_s}$, etc., is a series of equal quantities—each equal to 100 $e^{-\mu x'} - d$.

These last two deductions provide very simple tests for exponential absorption, and judging by these, a glance at the absorption curves given in Figs. 4 and 7 and at the percentages shown in Table I makes it evident that the β-rays of *Ra.E.* do not comply with these requirements.

The explanation has been slowly forthcoming. The loss of intensity in passing through matter is brought about in two ways, i.e., (1) By the particles being slowed down or stopped, the energy going probably into ionization and possibly a small part into the production of X-rays.

(2) By the particles being scattered by collision with the atoms of the absorbing material. It is obvious that the scattering loss will be greater the less the velocity of the particles.

In 1900 Becquerel showed photographically by magnetic deflection that the β-rays from radium are not homogeneous. W. Wilson (Proc. R.S., 1909) used this method to isolate an approximately homogeneous beam of β-rays of velocity v, by magnetic deflection in a circle of radius R, under a field of strength H, the velocity being given by the well-known relation $\frac{m\,v}{e} = H.R.$ His results showed that the absorption was not exponential but that the rays became more and more absorbable as the thickness of absorbing material was increased He further showed that the absorption increased rapidly as the velocity diminished and in no case could be called exponential.

One of the best series of experiments on homogeneous β-rays is that of Crowther (Proc. R.S., 1910). One of his curves showing absorption in aluminium is reproduced in Fig. 2, which indicates that for very thin layers there is practically no absorption (similar to the results obtained with α-particles). The increasingly large scattering effect, however, soon alters the slope of the curve and the relative absorption is seen to increase as the thickness of aluminium is increased.

By putting a thin plate of platinum (.001 cm. thick) over the active material and then absorbing in aluminium Crowther found that the curve obtained was very nearly exponential, showing that the character of the rays had been altered by passage through a substance of such high scattering power as platinum.

Later experiments of Wilson and von Baeyer showed definitely that β-rays lose velocity in passing through matter and consequently

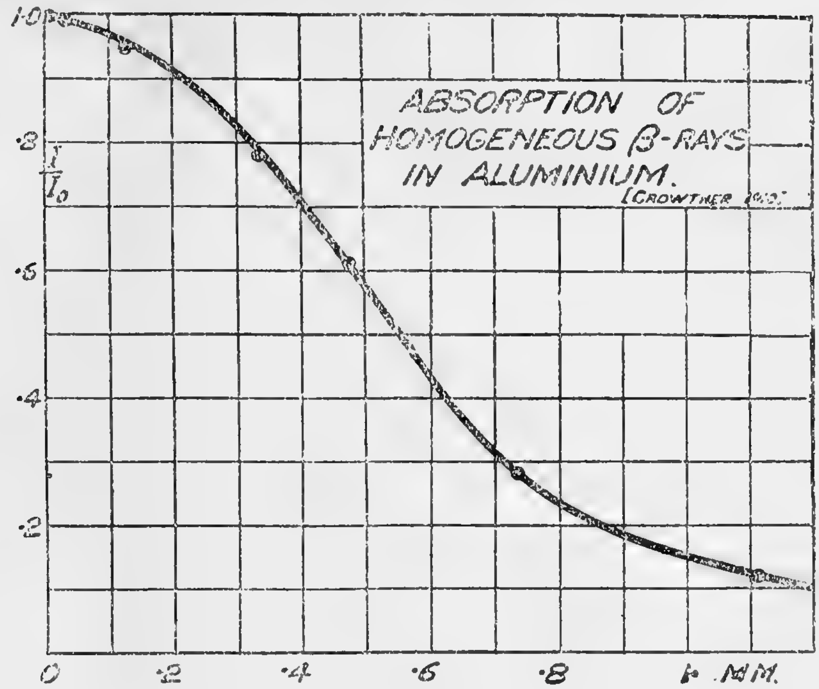

Fig. 2

must have an "effective range," i.e., if there be a given stream of β-rays of any one type there must be some definite thickness of any absorbing material through which the β-rays cannot be detected no matter how great their original intensity.

A very complete description of the experiments referred to above is given in Rutherford's "Radioactive Substances and their Radiations".

It was pointed out by J. A. Gray (Proc. R.S., 1912) that, if β-rays like those from *Ra.E* appear to be exponentially absorbed at first, this can only be an approximation, and a stage must be reached when the absorption increases more and more rapidly until finally the effective range is reached. The values of such terms as $\frac{100\ I_s}{I_r}$, etc. (referred to above), become less and less, the limit being zero when the range is reached. The range can only depend on the fastest β-rays in the original beam, and hence this affords a method of measuring the relative maximum speeds of β-rays from different radioactive substances.

At the suggestion of Dr. Gray, the writer has carried out a series of experiments following the lines indicated above with two main objects:

(1) To determine whether β-rays lose velocity when scattered through large angles.

(2) To determine the ranges of the β-rays in different substances and the relation between range and atomic number.

PART I

When electrons strike a metal anticathode, X-rays are produced. In the same way, when β-rays impinge on matter, a metal plate for example, secondary γ-rays are produced, some of the β-rays are absorbed, some are scattered, and some are transmitted if the plate be not too thick. The question arises as to what relation exists between these various factors. If the γ-rays are due to the scattering of the β-rays then the scattered β-rays should show a loss of energy comparable to the energy of the γ-rays produced. If no such loss is detectable we are justified in assuming that γ-rays are not produced when β-rays are scattered, but when they are stopped by some particular type of collision.

The experimental procedure was as follows: The preparation of *Ra.E* was enclosed in a small lead case (*A*) (see Fig. 3), with one open face and was mounted centrally in front of, but turned away from, the foil face of the electroscope. The latter was a 14 cm. cube. Between it and the active material was placed the absorbing material (*B*), and in front of the active material stood the radiator (*R*). Thus only rays scattered through approximately 160° to 180° could enter the electroscope.

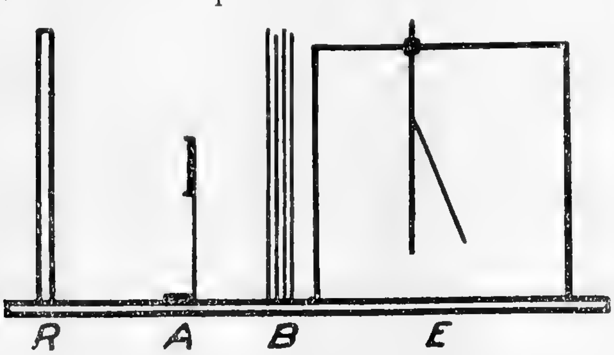

Fig. 3

The intensity of the direct radiation was obtained by replacing the radiator by the active material with its open face towards the electroscope.

Corrections had to be made in both cases for γ-rays. This is possible to a high degree of accuracy if the mass-absorption coefficient for γ-rays be known. Those coefficients have been determined for various substances, including carbon and aluminium, by Dr. Gray, who has shown that whereas the mass-absorption coefficient of β-rays in carbon is approximately 16, that of γ-rays in carbon is 0.100. In the case of the scattered radiation a further correction was necessary to eliminate the effect of air-scattering. This presented no greater difficulty than the careful repetition of every reading with the radiator completely removed.

Table I shows the results obtained for (1) Absorption of primary β-rays; (2) absorption of β-rays scattered from a lead radiator, 3 mm. thick; (3) absorption of β-rays scattered from a silver radiator, 0.3 mm. thick. The absorber in each case was paper, each sheet of which weighed 0.00848 gms. per sq. cm.

TABLE I

Absorber		Primary rays		Scattered rays			
				Lead		Silver	
No. of Sheets	Mass gm/cm²	Intensity	$\frac{100\ I_s}{I_r}$ %	Intensity	$\frac{100\ I_s}{I_r}$ %	Intensity	$\frac{100\ I_s}{I_r}$ %
0	0	12000	....	....	....	....	....
6	.0509	4988	....	2000	....	2000	....
11	.0933	2688	54.0	907	45.4	780	39.0
16	.1357	1488	55.3	365	40.3	278	35.6
21	.1781	706	47.5	125.5	34.4	91.5	32.9
26	.2205	311	44.0	39.0	31.1	27.1	29.7
31	.2629	117.92	37.9	10.46	26.8	6.88	25.4
36	.3053	37.22	31.6	2.31	22.1	1.63	23.7
41	.3477	10.22	27.5	0.43	18.7	0.33	20.4
46	.3901	2.52	24.6	0.041	9.5	0.028	8.3
51	.4325	0.50	19.8	....	....	....	....
56	.4749	0.02	4.0	....	....	....	....
61	.5173	0.00	0	....	....	....	....

In Fig. 4 are given the curves corresponding to (1) and (2) above mentioned.

These results point very definitely to the fact that the scattered rays have a range only slightly less than that of the primary rays, because it is certain that practically no primary rays go beyond 57 sheets, while in the case of the secondary rays it is certain that some do pass 49 or 50 sheets. This represents at most only 10 per cent. or 12 per cent. loss of energy as a result of scattering, and for the following reasons it will be shown that this is considered an upper limit, the actual loss being probably very much less, if indeed it exist at all.

(1) It should be noted that only a small proportion of the rays emitted have a very high velocity and it is the effect of this small proportion which has to be accurately measured as the range is approached. From the table it will be seen that at 56 sheets the intensity of the primary rays has been cut down to 1/500,000 of its original value. The difficulty of measurement arising from this reduction comes into play sooner in the case of scattered radiation since the original intensity is much less, and the proportion of high velocity rays is lower since they are less likely to be deflected than the

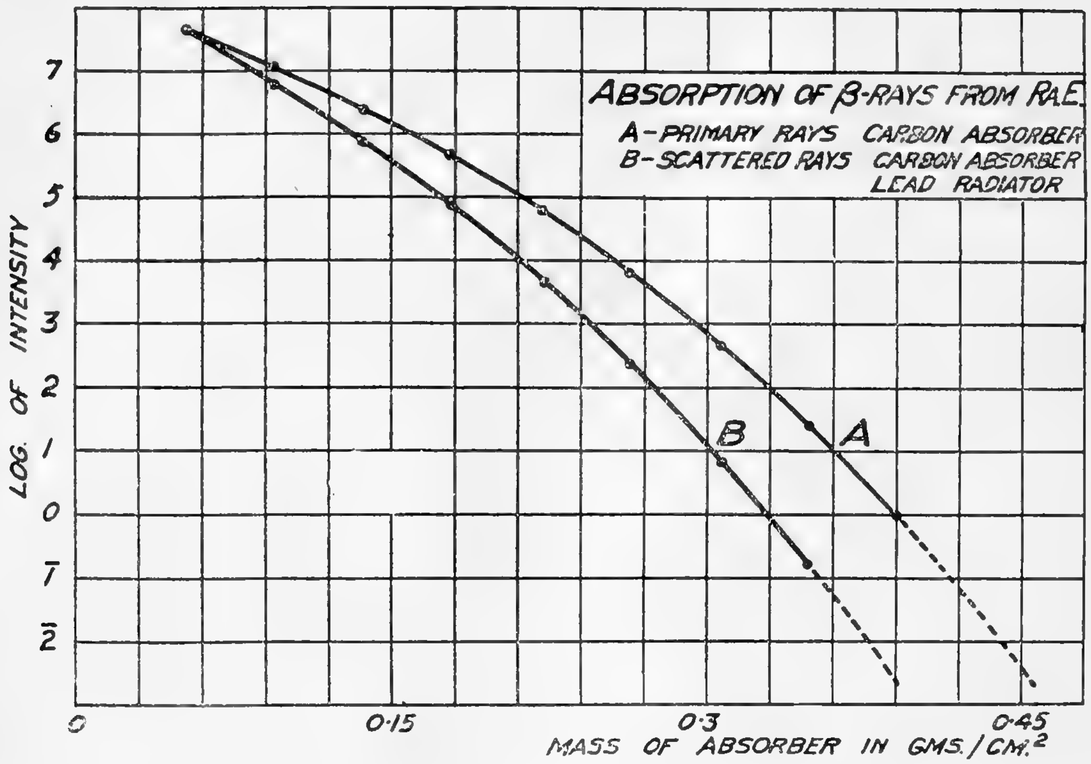

Fig. 4

slower ones. Intensities of this order are much smaller than the natural leak and consequently a slight fluctuation of leak will give a very large error in the apparent intensity.

For these reasons it seems almost certain that with a very intense source of radiation and a more precise method of measurement a measurable quantity of scattered radiation would be detected through a mass of absorber more closely approaching the range of the primary rays.

(2) Scattering is not a surface phenomenon (see Fig. 5). Some of the β-particles will have penetrated a considerable distance into the radiating material before being deflected back, and some will undergo several deflections inside the radiator before emerging backwards. Hence there will be an average distance inside the radiator which the scattered particles traverse, and while doing so they will lose velocity just as has been shown to be the case whenever β-rays pass through matter. It is evident, then, that the real range of the scattered rays is the range actually found plus the equivalent of the average path in the radiator. It is not impossible, though it cannot yet be stated definitely, that this

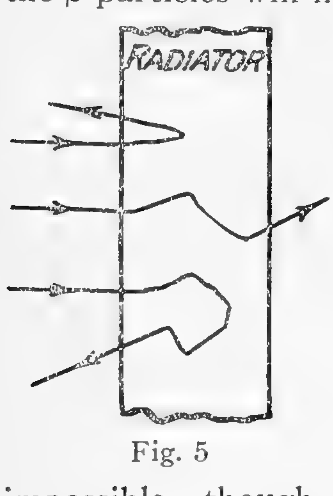

Fig. 5

completely explains the apparent difference in range between the primary and scattered rays, and if so, it may be said that to a first approximation there is no loss of energy due to scattering.

(3) This conclusion is confirmed by the following theoretical considerations:

In the Phil. Mag., Vol. 27, 1914, p. 499, C. G. Darwin gives the calculations regarding the collisions of α-particles with light atoms. In the Phil. Mag., Vol. 21, 1911, p. 684, Sir E. Rutherford states that collisions with light atoms by α and by β-particles obey the same general laws; the main difference being that the probability of a large deflection is much greater in the case of the β-particle due to its mass and its momentum being so much less than the mass and momentum of the α-particle.

It seems reasonable, then, to employ Darwin's method of approach, extending his reasoning to the problem of energy loss.

Consider the deflection of a β-particle of mass M and velocity V due to collision with the nucleus of an atom of mass m at rest. Let ϕ be the deflection of the β-particle and v its resultant velocity; and let the atom be set in motion in a direction θ with a velocity u.

The equations of motion are:

$$MV = Mv\cos\phi + mu\cos\theta$$
$$0 = Mv\sin\phi - mu\sin\theta$$
$$MV^2 = Mv^2 + mu^2$$

and hence $$v = \frac{V}{M+m}\left(M\cos\phi \pm \sqrt{m^2 - M^2\sin^2\phi}\right)$$

The energy of the β-particle before collision was $\frac{1}{2}MV^2$. Its energy after collission is

$$\tfrac{1}{2}Mv^2 = \tfrac{1}{2}M\left(\frac{V}{M+m}\left(M\cos\pm\sqrt{m^2 - M^2\sin^2\phi}\right)\right)^2$$

Hence the loss in energy is given by:

$$\tfrac{1}{2}MV^2\left(1 - \frac{1}{(M+m)^2}\left(M\cos\phi \pm \sqrt{m^2 - M^2\sin^2\phi}\right)^2\right)$$

In the particular case of scattering through an angle of 180°, this loss of energy becomes $\frac{1}{2}MV^2\left(1 - \left(\frac{-M\pm m}{M+m}\right)^2\right)$

The lower sign gives zero, while the upper sign gives:

$$\tfrac{1}{2}MV^2\left(1 - \left(\frac{m-M}{m+M}\right)^2\right)$$

In the case of β-particles scattered by hydrogen $M = \frac{1}{1800}m =$

1.008, and it is evident that the loss in energy is of a very small order being 1 in 460 or 0.216 per cent. If this theory could be applied to heavy atoms such as lead (207) and silver (108), then the loss in energy is seen to be almost non-existent, actually for lead 0.00105 per cent.

This analysis is based on the assumption that the collision is of the nature of the passage of a comet around a large star, that is to say, considerations of energy-loss due to radiation, and of alteration of mass with velocity are neglected. These points would require special treatment. It is true that, unlike the case of the α-particle, a large deflection of a β-particle may sometimes be the result of many collisions whereby the electron has been buffeted about in an erratic manner for possibly a considerable time before it finally emerged in the direction from which it entered. But on the above theory it would require 10,000 collisions with lead atoms to produce a 10 per cent. loss in energy.

It is, therefore, concluded that the loss in energy is certainly much less than 10 per cent. and is possibly zero.

This is a point of considerable theoretical importance, as it indicates that the phenomenon of the scattering of β-rays does not furnish an explanation of the production or excitation of γ- or X-rays.

PART II

The complex β-rays emitted from a source like *Ra.E* can be represented by a Velocity Distribution Curve of the type of the Maxwellian Probability curves. There will be a minimum velocity v_0 (see Fig. 6) near the origin below which β-rays do not ionize and hence are not detectable as β-rays. The curve will begin at this point, rise to its maximum over $\bar{v}$, where $\bar{v}$ is the most probable velocity, and then fall to a point just short of c where c is the velocity of light. The presence of an absorbing plate in the path of the rays causes a two-fold change: (1) in the shape of the curve, $\bar{v}$ approaching v_0 as the velocity of the transmitted rays is decreased; (2) in the

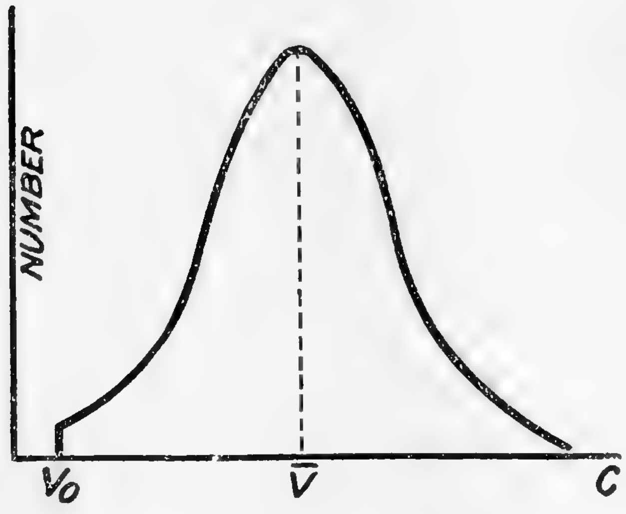

Fig. 6

area under the curve, as some of the rays are stopped or absorbed, and others are scattered through angles greater than 90°.

It is of interest to note that the exponential law of absorption requires that, to a first approximation, the rate of decrease of area under the curve should be constant, due to the combined effects of absorption and scattering through angles greater than 90°, and it may be remarked again that this is proved not to be the case, the area actually decreasing more rapidly as the thickness of absorber is increased.

As the area diminishes and $\bar{v}$ approaches v_0 there will come a time when even the fastest particles have been slowed down so much that they cannot escape complete absorption, hence a range must exist, and that thickness of absorber may be termed the "effective range" which makes the whole curve shrink finally to v_0. The "actual range" which is not directly obtainable experimentally will be referred to later.

The determination of the range in different substances was made by the following method:

A 10 cm. cube electroscope, the base of which consisted of one sheet of aluminium foil (.004615 gms/cm^3) and one sheet of paper (.00848 gms/cm^2), was mounted on the pole pieces of an electromagnet. The active material was placed 6 cm. below the electroscope. The magnetic field was sufficiently strong to deflect between 40 per cent. and 50 per cent. of the primary β-rays unabsorbed, and when their velocity was reduced by about 40 sheets of paper, or its equivalent, complete deflection of the β-rays took place. For small amounts of absorber the intensity with the field off exceeds the intensity with the field on. As the thickness of absorber is increased this excess is diminished until, when the range is reached, the intensities are the same whether the field be off or on.

The difficulties encountered in those experiments, as in all those carried out during the course of the investigation, arose in two ways: (1) The variability of the natural leak and its continued high value and the extreme sensitivity of the electroscope to air currents in spite of the precaution of placing draught-screens around three sides of the apparatus and protecting its base by several layers of absorber; (2) the comparative weakness of the active material which was used for the majority of the experiments, making accurate measurements very difficult when the reduction of intensity was of the order of 1 in 500,000, as has already been explained.

As a result of these, the exact location of the range was not possible to the degree of precision hoped for, but the extreme limits were found by repeated observations and the values shown in Table II as "Average Range" are accurate probably to 0.01 gm. per sq. cm. A correction was necessary due to the permanent base of the electroscope, and the values obtained after this has been made are given under the heading "Corrected Range."

TABLE II

Effective Range of β-Rays from Ra.E.

Absorbing Material	Atomic number	Average range (gms/cm²)	Corrected range (gms/cm²)
Carbon	6	.462	.474
Aluminium	13	.448	.460
Copper	29	.421	.432
Tin	50	.385	.395
Lead	82	.345	.354
Foil {40 per cent. *Sn*, 60 per cent. *Pb*}	(69)	.362	.371

The values here shown can only be considered as the result of preliminary experiments which the writer hopes to continue at some future date.

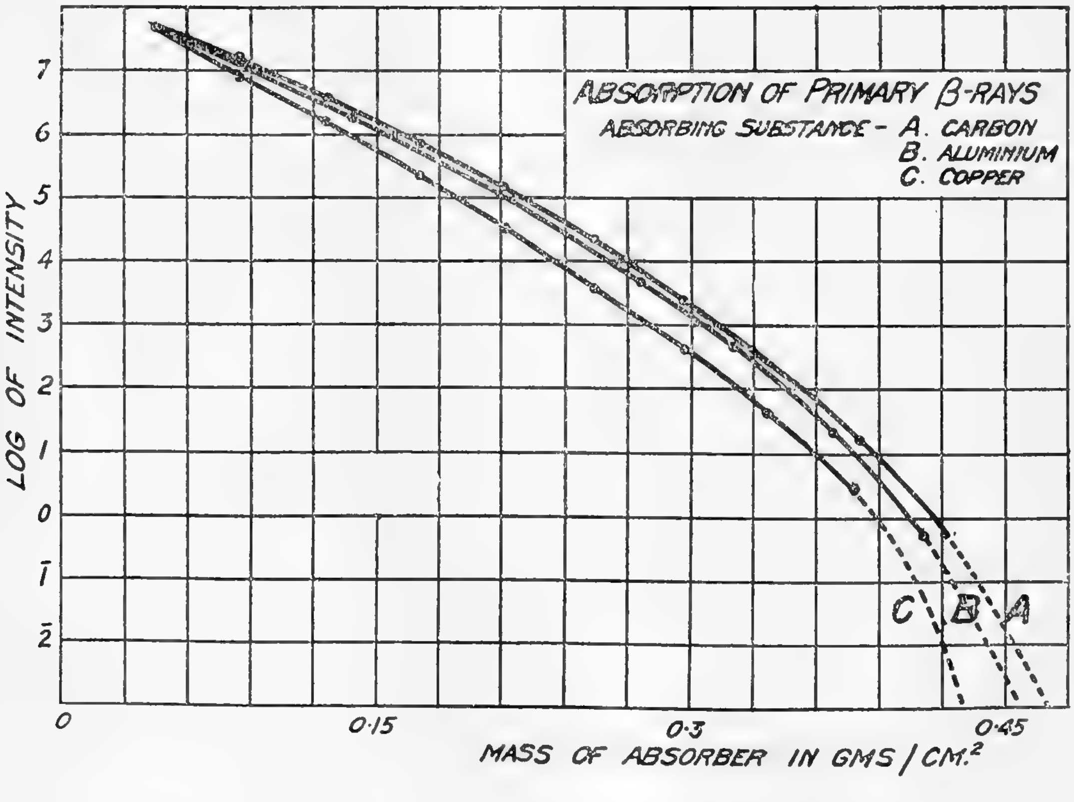

Fig. 7

In Fig. 7 are shown the absorption curves terminating the ranges for carbon, aluminium and copper.

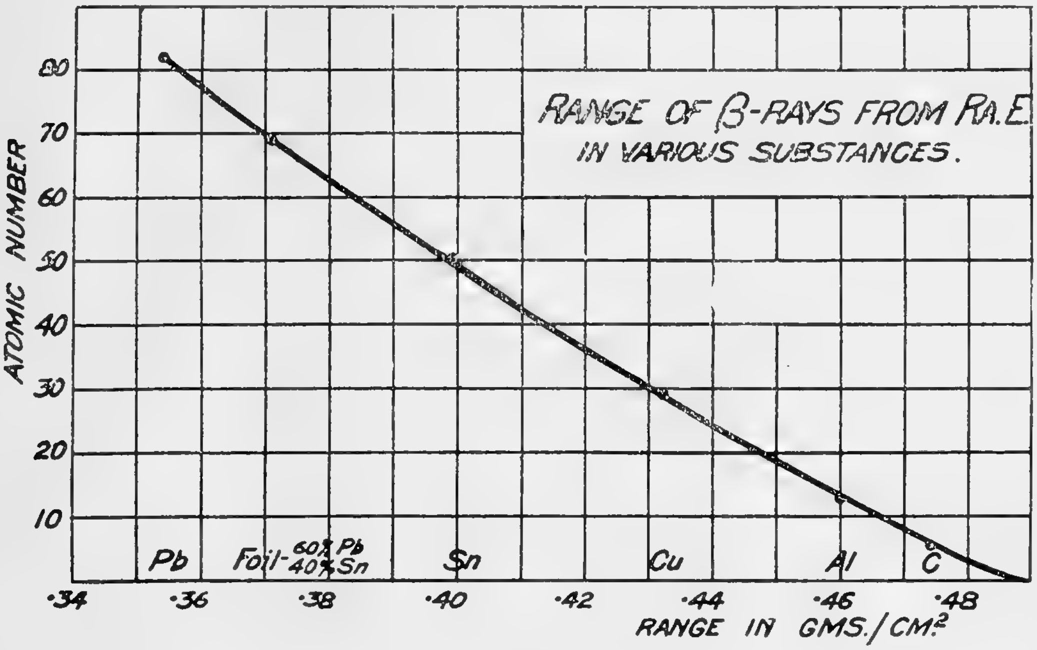

Fig. 8

In Fig. 8 the range has been plotted against the atomic number, and a smooth curve is found to result. It would be necessary, however, to examine the range in many more substances before the relation between effective range and atomic number could be definitely established. By analogy to Crowther's and McClelland's curve of mass-absorption coefficients against atomic number, and Bragg's curve of molecular diameters against atomic number, it seems a plausible forecast that a broken curve of that nature might be found, the breaks occurring at the atomic numbers of the inert gases.

The range of α-particles in different substances has been found by Bragg and Kleeman (Phil. Mag., 1905) to vary very nearly as the square root of the atomic weight. At first sight it appears strange that the range of the β-particle should follow an entirely opposite law and decrease with increase of atomic weight.

This leads to the distinction already referred to between effective and actual range. It will be seen from Table II that the effective range decreases very slightly for large increases in the atomic number of the absorbers. On the other hand, it has been shown by Schmidt and others that the coefficient of scattering increases very rapidly with atomic number. This means that the amount of scattering from plates of equal mass per unit area increases the higher the atomic number of the substance of which the plate is made. The following figures illustrate the increase: Aluminium, 9.7; copper, 70; tin, 100; lead, 266. A high coefficient of scattering means that the β-particle is subjected to many more collisions and consequently its path inside the absorber is composed of many short zigzag paths. The total path or sum of all these separate short paths within the absorber is what is meant by the actual range, where as the effective range is the perpendicular distance from one face to the other. If the actual range could be accurately estimated on the basis of the coefficient of scattering, it seems certain that it would be found to increase as the atomic number increases. Indeed, by means of a special experiment W. H. Bragg, (Phil. Mag. 1910) has shown that this is the case.

The writer desires to express her thanks to Dr. J. A. Gray for his continuous help and valuable suggestions.

Summary

1. Experimental evidence is given to prove that when β-rays are scattered through large angles the loss of energy observed is not more than about 10 per cent.

2. Reasons are given for believing that the actual loss of energy is so much less than 10 per cent. that to a first approximation it may be said that there is no loss of energy due to scattering.

3. The effective ranges of β-rays in carbon, aluminium, copper tin, lead and mixed foil are given.

4. The distinction is drawn between "effective" and "actual" range and evidence is given to support the statement that whereas the effective range decreases with increase of atomic number, the actual range increases with increase of atomic number.

Primary and Secondary β-Rays

By J. A. GRAY, F.R.S.C.

(Read May Meeting, 1922)

In the previous paper in these Transactions, Miss A. V. Douglas has given an account of measurements of the absorption and effective range of the β-rays of radium E in various substances. Using paper as absorbing material, the writer[1] carried out similar experiments in 1912, including some on the secondary β-rays excited in lead by X-rays[2] which had been formed by the β-rays of radium E (the primary β-rays) in another piece of lead. In this paper an account will be given of these experiments on secondary β-rays. This term secondary β-rays is here confined to β-rays excited by X-rays.

As a source of X-rays the following arrangement was used. A strong preparation of radium $(D+E)$ was placed between two plates of lead 0.1 mm. thick and the lead was covered above and below by plates of graphite 3 mm. thick. The latter precaution was necessary because the lead plates were not thick enough to absorb all the primary β-rays. Under these circumstances, about 80 per cent. of the rays coming through the graphite have been formed by primary β-rays in the lead. The remaining rays are γ-rays from radium D. Previous experiments[3] had shown that the combined rays have a mass absorption coefficient in lead of 3.88 (for small thicknesses only) and 0.074 in carbon. These rays, therefore, excite a very much larger number of secondary β-rays in a thin sheet of lead than in a corresponding sheet of paper. This being the case we can examine the secondary β-rays from lead in the manner described below.

To measure their intensity an iron electroscope of 15 cm. cube was used. The bottom of it was cut out and replaced by very thin aluminium leaf, appropriately supported by wires. The source of X-rays was placed below the electroscope, and a sheet of lead foil 0.0173 gramme/cm.^{2} placed above it. The foil was first placed just beneath the electroscope, then 9 mm. away and finally 1.7 cm. In this position of the foil sheets of paper, each of mass 0.00877 gramme/cm.^{2}, were placed above the foil. The reading of the electroscope was

[1]Gray, Roy. Soc. Proc., Series A, vol. 87, p. 487, 1912.

[2]It has been thought preferable to use the term X-rays instead of γ or secondary γ-rays which the writer has used in previous papers. The term γ-rays is here confined to γ-rays from radioactive substances.

[3]Gray, Roy. Soc. Proc., Series A, vol. 87, p. 489, 1912.

found in divisions per minute. The results obtained are given in Table I, the initial readings in column 3 of the table.

TABLE I

Absorbing Material	Mass in gms/cm²	Divisions per minute	Intensity of Secondary β-rays	
			Uncorrected	Corrected
0.0		25.6	18 6	14.9
0.9 cm. of air	0.00011	17.2	10 2	8.9
1.7 " " "	0.00021	16.7	9.7	8.6
air+1 paper sheet	0.00893	11.36	4 36	4 13
air+2 paper sheets	0.0177	9.46	2 46	2.41
air+3 paper sheets	0.0265	8.86	1 86	1 86
air+4 paper sheets	0.0353	7.80	0.80	0 80
air+5 paper sheets	0.0440	7.40	0 40	0.40
air+6 paper sheets	0.0528	7.18	0 18	0 18
air+22 paper sheets	0.1953	7.00	0 00	0.00
air+30 paper sheets	0.2655	6.98	....	...

The readings in column 3 are for the combined effects of: (1) secondary β-rays entering the electroscope from below, (2) X-rays and γ-rays which have passed through the absorption sheets. The mass absorption coefficient of the latter in paper being 0.074, the absorbing layers of paper have very little effect on their intensity. Consequently, a standard reading of 7 divisions per minute was taken as the intensity due to (2). Subtracting this from the figures in column 3, we get those in column 4. Another correction has to be made because of the β-rays excited by the γ-rays of radium D, the initial intensity of such β-rays being about 20 per cent. of the total *i.e.*, one of 3.7 divisions per minute.

A special experiment similar to that described above showed that the following figures represent the absorption of the β-rays formed by the γ-rays (see Table II), the initial intensity being taken as 3.7.

TABLE II

Absorbing material	Intensity of β-rays excited by γ-rays
0.0	3.7
0.9 cm. of air	1.30
1.7 " " "	1.08
1.7 cm. of air+1 paper sheet	0.23
" +2 paper sheets	0.05
" +3 paper sheets	0.00
" +6 paper sheets	0.00

Subtracting these figures from those in column 4 of Table I we get finally the figures in column 5.

The results of the initial experiments on the primary rays are given below in Table III, intensities being given in arbitrary units, and for the sake of comparison, corresponding intensities of the secondary β-rays have been placed in column 4.

TABLE III

Absorbing material	Mass in gms/cm²	Intensity of Primary β-rays	Intensity of Secondary β-rays
0.0	....	1301	1301
1 paper sheet	0.000877	1081	347
6 paper sheets	0.0526	540	16.3
11 " "	0.0965	279	0.0
16 " "	0.1403	155	....
21 " "	0.1842	72	....
26 " "	0.2280	34.3	....
31 " "	0.2719	14.2	....
36 " "	0.3157	5.5	....
41 " "	0.3596	1.8	....
46 " "	0.4034	0.43	....
51 " "	0.4473	0.05	....
56 " "	0.4911	0.00	....

The secondary β-rays have their origin in the lead foil and therefore lose energy before they escape from it. We can, however, neglect this loss of energy when making a comparison between the velocities of primary and secondary rays, because, according to the measurements of Miss Douglas, the primary β-rays are only just stopped by lead of mass 0.354 grammes/cm.², or lead 20 times a thick as that in which the secondary β-rays originate.

We see at once from the tables that a very large percentage of the secondary β-rays have slower velocities than the primary β-rays, since 80 per cent. of the primary rays pass through one sheet of paper as compared with 30 per cent. of the secondary, and 40 per cent. of the primary rays pass through 6 sheets of paper as compared with 1.2 per cent. of the secondary rays. It is impossible to compare accurately the average energy of a secondary β-ray with that of a primary, but a rough comparison may be made as follows. The primary rays are reduced to half value by 5 sheets of paper, the secondary rays to the same extent by one sheet of paper. A table is given on page 243 of Rutherford's "Radioactive Substances and their Radiations" which indicates that when absorption coefficients of β-rays vary as 5 to 1, the energies of such β-rays vary as 3 to 10. If we take this to be the case the average energy in a secondary β-ray is 30 per cent. of that of a primary β-ray. The reason that the average energy in a secondary β-ray is less than that of a primary ray is because a β-ray loses energy before it has a chance of exciting X-rays and further, when this takes place, the whole of the energy of the β-ray may not always be given up.

These results alone prove that secondary β-rays, at least after their ejection from the parent atoms, can play very little part in the production of the secondary X-rays (see the next paper in these Transactions) which are always formed in any substance struck by any beam of X-rays (the primary X-rays). We know that X-rays of frequency n eject secondary β-rays of energy hn where h is Planck's constant, and that β-rays of energy E may excite X-rays of frequency E/h but not of higher frequency. Suppose we now have a beam of primary X-rays of frequency n. This beam will eject β-rays of energy hn. These β-rays will excite secondary X-rays of average frequency much less than n, because, according to the result obtained above, the β-rays, excited in turn by such secondary X-rays will have an energy much less than hn. When we come to examine the secondary X-rays we find that their frequency, although lower than that of the primary, is of the same order. Consequently the percentage of them produced by secondary β-rays must be negligible. Ultimately any beam of X-rays will be transformed into β-rays. The β-rays, as we have seen, give rise to X-rays of smaller frequency. These X-rays in their turn eject β-rays, which will excite X-rays of still smaller frequency, and so on. The reasons for this have been referred to above.

It should be explained that most of the results in this paper were obtained in the last week that the writer spent in 1912 in the Physical Laboratories of the University of Manchester, and his thanks are due to Sir Ernest Rutherford for the use of the active material employed.

The Softening Exhibited by Secondary X-rays

By J. A. GRAY, F.R.S.C.

(Read May Meeting, 1922)

In this paper the term secondary X-rays has no reference to ordinary characteristic radiations, but will be confined to those X-rays which are given off in all directions from any substance (the radiator) struck by any beam of X-rays (the primary rays) and which are dependent in quality or frequency on that of the primary rays. The quality of such secondary rays is, for radiators of small atomic weight, independent of the nature of the radiator. Until recently, it was thought that these secondary X-rays were identical in quality with that of the primary and, as a rule, they have been called scattered X-rays.

In 1913,[1] however, the writer showed that secondary γ-rays were less penetrating or softer than primary γ-rays, a radium salt being used as a source of γ-rays. It was then shown that this "softening" was due to a real transformation of the primary rays and that it increased with the angle between the primary and secondary rays (usually called the angle of scattering). These results were confirmed by Florance[2] in 1914 and A. H. Compton[3] in 1921. In 1920,[4] it was shown that the same phenomenon was true for ordinary X-rays but was not so marked and consequently had escaped attention, although in 1913 Sadler and Mesham[5] published results which indicated that secondary X-rays were softer than primary X-rays. The first experiments of the writer with X-rays were performed in 1919 at University College, London. These experiments have not hitherto been published in detail and a short account of them will be given below.

A beam of primary X-rays, covering a comparatively narrow range in frequency, was obtained by filtering the rays from an X-ray tube through a screen of tin. The tube was operated by means of an induction coil and with a parallel spark gap of about 3.6 cm. between brass balls 2 cm. in diameter. Figure 1 shows that the rays were comparatively homogeneous. It was obtained by first passing the

[1]Gray, Phil. Mag. 26, p. 611, 1913.
[2]Florance, Phil. Mag. 27, p. 225, 1914.
[3]A. H. Compton, Phil. Mag. 41, p. 749, 1921.
[4]Gray, Journ. Frank. Inst, p. 633, 1920.
[5]Sadler and Mesham, Phil. Mag. 24, p. 138, 1912.

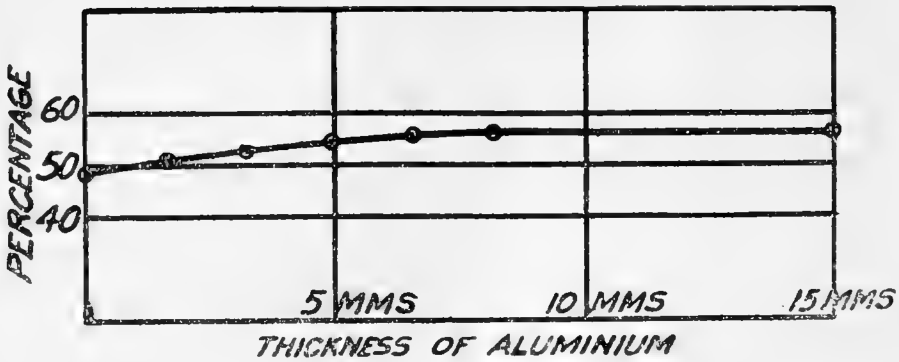

Fig. 1

primary beam through various thicknesses of aluminium and then, after that, the percentage intensity of the rays passing through a sheet of aluminium 1.63 mm. thick was found. In the figure this percentage intensity has been plotted against the thickness of aluminium, through which the primary beam had previously passed.

The softening and consequent decrease in frequency of the secondary X-rays was shown in the following manner (see Fig. 2).

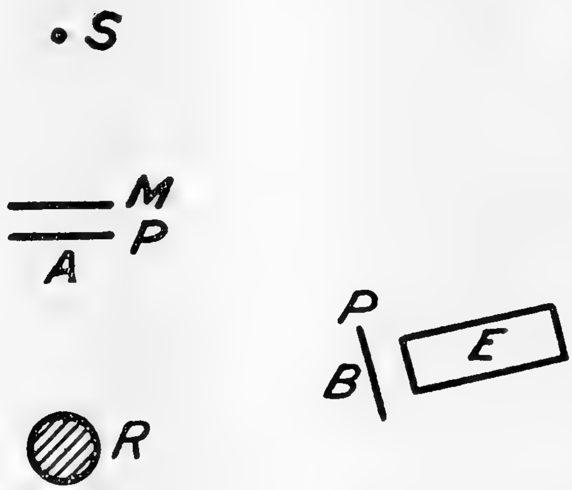

Fig. 2

S represents the source of X-rays, *M* the tin filter, *R* the radiator which, unless otherwise stated, was a block of paraffin wax, and *E* the ionization chamber of an X-ray spectroscope, the slits of which had been removed. The intensity of the secondary rays entering *E* was measured by a Wilson electroscope. The chamber *E* was appropriately screened so as to reduce the intensity of extraneous radiations to a minimum. The same absorption plate *P*, usually of aluminium, was alternately placed in positions *A* and *B*. Under these circumstances it can be shown that (except for a small correction), if the primary and secondary rays are identical in quality or frequency, the intensity of the secondary X-rays should be the same in either case.

Let us suppose that the two radiations are identical in quality. We will also assume that the plate P lets through a fraction p of the rays and that the radiator R sends towards the chamber E a fraction k of the rays falling on it. If the primary beam has an initial intensity I and the plate P is in a position A, the intensity of the primary rays reaching R will be pI and that of the secondary rays entering the chamber E will be kpI. In a similar manner it can be shown that the intensity of the secondary rays entering E when the plate P is placed in position B will be equal to pkI. Now let us suppose that the primary beam consists not of one but of n types, of intensities $I_1, \ldots I_r, \ldots I_n$, respectively. In both positions of the plate P the intensity of the secondary X-rays entering the chamber E will be

$$\sum_{r=1}^{r=n} p_r \, k_r \, I_r.$$

On the other hand, if the secondary rays have undergone a softening or decrease in frequency, the intensity of the rays entering the chamber E will be smaller when the plate P is in position B than when it is in position A. Table I shows the results obtained when the angle between the primary and secondary rays was 110°. By ratio A/B is meant the ratio between the intensity of the secondary rays entering E when the plate P was in position A to that when it was placed in position B.

TABLE I

Mass in gms/cm² of the plate P	Percentage of the primary rays transmitted	Ratio A/B
0.442	49	1.14
0.884	25	1.29
1.326	13.3	1.45
1.786	7.1	1.60

The above table shows that the secondary X-rays are softer than the primary rays, i.e., that there has been a transformation to rays of lower frequency. We find, for example, that a plate of aluminium of 1.768 grammes per cm.² lets through 7.1 per cent. of the primary rays but only 7.1/1.6 or 4.44 per cent. of the secondary. From these results it can be shown that the primary rays have a mass absorption coefficient in aluminium of 1.49, while the secondary rays have one of 1.76, an increase of 18 per cent. This increase in absorption coefficient was, within experimental error, independent of the thickness of the plate P, an indication that practically the whole of the secondary rays are softened. If there had been no change in frequency all the figures in column 3 of the table would have been practically equal to 1.00.

Similar results to those outlined above were obtained with aluminium and water radiators so that, for radiators of low atomic weight, the softening of the secondary rays was independent of the nature of the radiator. Results recently obtained indicate that, with soft X-rays, the softening is somewhat greater with radiators of high atomic weight.

That the effect found above was not a spurious one was decisively proved in the following manner. The average frequency in the primary beam was a little greater than the characteristic absorption frequency of silver. Consequently, if the secondary rays had a lower average frequency, they would possibly have a lower absorption coefficient in silver than the primary rays. This would, of course, depend on the magnitude of the change. To test these points, the same angle of 110° was used, the primary rays were hardened somewhat by a plate of aluminium 1.63 mm. thick, and the plate P was of silver of mass 0.103 gramme per cm.^{2} The ratio A/B turned out to be 0.57, the mass absorption coefficient of the primary rays in silver being 17.6, that of the secondary rays 12.8. Further experiments showed that the softening of the secondary rays was not so marked as the angle they made with the primary rays became smaller. For small angles the effect is negligible.

In these experiments the primary beam was not strictly homogeneous but A. H. Compton,[6] using as a primary beam one reflected from a crystal, has shown that there is a change in the secondary rays similar to that found when ordinary X-rays of corresponding penetrating power are used. He has found that, particularly with small angles between the primary and secondary rays, part of the secondary radiation is of the same frequency as that of the primary.

In these papers Compton suggests that the softened radiation is produced by the secondary β-rays which are always ejected from the radiator when it is struck by the primary beam. On the other hand, the writer has always been of the opinion that the effect could not be explained in this way. The following considerations show why this point of view has been taken. Secondary β-rays may excite X-rays (1) in collision with atoms of the radiator; (2) during the course of their expulsion from the parent atom. At first, Compton thought

[6]A. H. Compton, Phys. Rev., vol. 18, p. 96, 1921; Nature, Nov. 17, p. 366, 1921; Phys. Rev., vol. 19, p. 267, 1922.

that the secondary X-rays, at least those that differ in frequency from the primary, arose by the first mechanism, but found that the observed polarization of the secondary X-rays could not possibly be explained if this was the case. Other objections to (1) are that the secondary β-rays would not give rise to a sufficient intensity of secondary X-radiation, and further, the X-rays so formed would have a much smaller penetrating power than the bulk of the secondary X-rays (see previous paper in these Transactions).

The possibility of method (2) being the cause has been examined experimentally. As primary rays an unfiltered beam from a Coolidge tube with tungsten target was used, the tube being operated under a potential of about 30,000 volts. The first experiments were similar to those described above. Paraffin wax was used as radiator, the plate P was of aluminium and the angle between primary and secondary rays 90°. The results obtained are given in Table II.

TABLE II

Mass in gms/cm² of the plate P	Percentage of primary rays passing through P	Ratio A/B
0.304	32.7	1.13
0.608	15.2	1.24
0.912	7.9	1.32
1.216	4.3	1.40

From this table we find that the average mass absorption coefficient of the primary rays is about 3.00, that of the secondary rays 11 per cent. greater. From the observed ratio A/B it can also be found that the greater percentage of secondary rays have undergone softening or lowering of frequency. This, being the case, experiments were then carried out with thin radiators of paper, aluminium, copper and tin, with the intention of finding the relative intensities of the secondary X-rays from these radiators for a purpose discussed below. The angle between the primary rays and the secondary rays examined was again 90°. Table III shows the results.

TABLE III

Radiator	Mass in gms/cm²	Mass absorption coefficient of primary rays	Relative intensities per unit mass of secondary radiation
Paper	0.0638	1.00	100
Aluminium	0.0327	7.00	125
Copper	0.154	50.00	300
Tin	0.153	38.00	580

In the third column, corrections have been made for absorption of both primary and secondary rays in the radiator. From the previous results, we know that the greater part of the secondary rays have been softened. The relative intensities per unit mass of the secondary radiations should, therefore, bear some relation to the number of secondary β-rays formed per unit mass of the radiator. As a first approximation, we may take the number of β-rays to be proportional to the mass absorption coefficients. We find, however, that the relative intensities per unit mass of the secondary radiation bear no relation whatever with these absorption coefficients but merely show a gradual increase in intensity as the atomic number of the radiator is increased.

This gradual increase has been explained on the ordinary theory of scattering, electrons being closer together in an atom the higher the atomic number. As the scattered waves from neighbouring electrons re-enforce each other, we should get a greater intensity per unit mass of scattered radiation from elements of high atomic number than we do from those of low atomic number. This point of view is also borne out by the fact that, as we decrease the angle between primary and secondary rays, the relative intensities per unit mass of the secondary X-radiation show a larger rate of increase with atomic number than that given in column 3 of the above tables. For example, for an angle of 45°, the approximate numbers are paper 100, aluminium 160, copper 380 and tin 800.

It is, therefore, concluded that the observed change in frequency and consequent softening of secondary X-rays is not due to their being formed by secondary β-rays, and that every electron which the primary beam may influence in passing, plays a part in this phenomenon. A greater knowledge of the experimental facts relating to this very important question seems to be required before a satisfactory explanation of it can be given.

For the work carried out at University College, London, a grant was received from the British Scientific and Industrial Research Council, and for that carried out at McGill University, one from the Honorary Advisory Council for Scientific and Industrial Research.

The writer has much pleasure in expressing his thanks to Sir William Bragg for placing all the laboratory facilities at his disposal.

McGill University,
Montreal.
June 10, 1922.

Arc, Spark and Absorption Spectra of Argon

By W. W. SHAVER, M.A.

Presented by PROFESSOR J. C. McLENNAN, F.R.S.

(Read May Meeting, 1922)

A. *On the Arc and Spark Spectra of Argon*

I. *Introduction*

The resonance and ionization potentials of argon have been accurately determined by Rentschler,[1] Horton and Davies,[2] Déjardin[3] and others. The spectrum of the radiation produced by the bombardment of argon atoms with electrons of various speeds has also been studied by Déjardin,[4] using the well-known lamp of the three-electrode type with accelerating potentials varying from 16 to 80 volts. He found that with potentials from 16 to 33 volts the lines in the spectrum of the radiation produced all belonged to the red spectrum of argon. The blue spectrum which is due to the excitation of the ionized agron atoms began to appear with a field of 34 volts and the number of lines increased with increasing accelerating potential.

The author has repeated these experiments using potentials varying from 10.1 to 240 volts. The results obtained for the most part substantiate the work of Déjardin with this one exception. It was found that a visible radiation persisted with a voltage of 10.1 volts after the arc had once been struck, whereas Déjardin found that the lowest possible voltage required to excite radiation was between 15 and 16 volts and then it was only detected with an exposure of three hours. The production of this radiation with a grid potential of 10.1 volts, which is approximately the resonance potential of argon, required very exacting experimental conditions as to the gas pressure and the proximity of the filament to the grid, but it was found possible to photograph it with an exposure of half an hour. The spectrum obtained consisted of lines belonging to the red spectrum of argon and some bands, which were probably due to traces of gas impurities from the wax used with the quartz window.

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[1]Rentschler, Phys. Rev., Vol. 14, p. 503, Dec., 1919.
[2]Horton and Davies, Roy. Soc. Proc. A, Vol. 97, p. 1, March 1, 1920.
[3]Déjardin, Comptes Rendus, Vol..172, 1921, p. 1347.
[4]Déjardin, Comptes Rendus, Vol. 172, 1921, p. 1482.

Professor J. J. Thomson[5] has shown by positive ray analysis that the argon atom may lose several electrons, and it was hoped that by use of a high accelerating potential a third spectrum due to a highly ionized type of atom might appear. However, with a voltage of 240 volts between the filament and the grid no new lines were brought out.

II. *Description of Apparatus*

As there was no effort made to determine the resonance or ionization potential a simple lamp of the three-electrode type was used (see Fig. 1). The lamp made of Pyrex glass was cylindrical in shape, 15 cm. long and 3.5 cm. in diameter. Two electrodes of coarse tungsten wire were sealed in at one end and a 9 mil tungsten filament *F* was silver soldered to these electrodes. The other end of the lamp was closed by a quartz window securely sealed with wax. The grid *G* consisted of two concentric cylinders of fine iron wire gauze, having a mesh of 12 wires to the inch, the inner one being supported by the outer by means of short lengths of iron wire which were silver soldered to both. The inner gauze cylinder was about 1.5 cm. in diameter and the one end was closed by a circular iron plate *S*. Thus when the grid was in position the plate *S* prevented the light produced by the heated filament from reaching the slit of the spectrograph. The third electrode, which was also of tungsten wire, was sealed in the side of the lamp and silver soldered to the grid.

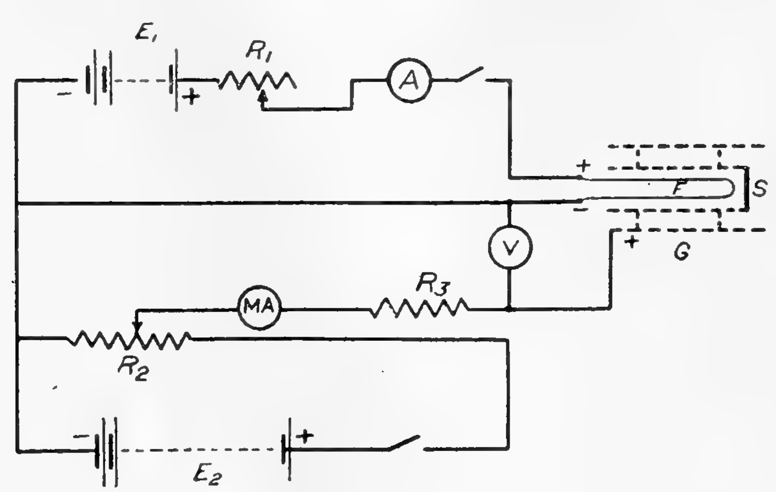


Fig. 1

All metal parts were first heated to red heat and then cleaned with acid. The lamp was then mounted in an electric furnace in such a way that the quartz window dipped in a water bath which

[5]Thomson, Rays of Positive Electricity, First Edition, p. 53.

prevented the wax from melting. Exhaustion was carried on for about twenty hours by means of a mercury pump and also a charcoal tube immersed in liquid air, the temperature of the furnace being maintained at 400°C. The filament was also heated to incandescence by passing a current through it while the lamp was being exhausted so that any gas which might be given off was removed. The argon gas was purified from a mixture of 80 per cent. argon and 20 per cent. nitrogen by repeatedly passing it over calcium turnings heated to 600°C., and after the pump and the charcoal tube were sealed off, some of this purified gas was admitted to the tube. The best gas pressure for the production of the arc was found by trial to be about 0.1 mm. of mercury, after which the lamp was sealed off and ready for use.

The electrical connections are also shown in Fig. 1. The current for the heating circuit was supplied by a 20 volt battery E_1, which was connected in series with a variable resistance R_1, an ammeter A, and the filament F. The grid voltage was obtained from a second battery E_2, which was short-circuited through a resistance R_2 of about 115 ohms. Any voltage not exceeding 240 volts, the maximum of the battery, could be applied between the filament and the grid.

III. *Experiments*

The heating current required to bring the tungsten filament to the temperature necessary for the emission of electrons was at first 5.8 amperes, but as the filament gradually evaporated and thus decreased in diameter this amperage was reduced by increasing the resistance R_1 so as to keep the electron supply constant. The electrons were given a definite speed depending on the grid voltage while traversing the distance between the filament F and the inner cylinder of the grid. Any electrons which passed through the meshes of the inner cylinder then entered the fieldless space between the cylinders, since the latter were connected by iron wire as previously described. When the grid voltage was sufficient to give the electrons the energy required to cause inelastic impact with the argon atoms, radiation was produced in the space between the cylinders. This was focussed on the slit of a large quartz spectrograph made by the Adam Hilger Company and photographed on Wratten panchromatic plates. It was found that with an exposure of half an hour good photographs were obtained. The current passing from the filament to the grid was kept as near to 35 milliamperes as possible, except in the case where the grid voltage was 10.1 volts when it fell to 10 milliamperes.

IV. *Results*

Photographs were taken with the following accelerating potentials: 10.1, 16, 19, 30, 31, 37, 40, 45, 55, 90, 105 and 240 volts. At 10.1 volts, which was the minimum voltage for radiation, the following lines belonging to the argon red spectrum appeared:

Intensity	Wave-lengths in Å.U.
0	4335.4
0	4300.2
1	4259.8
2	4198.4
2	4158.7
1	4055.9

A reproduction of the photograph taken is shown in Plate I(*a*). The faint lines are the ones whose wave-lengths have been given while the bands occurring at the wave-lengths 3806.4, 3562.0 and 3347.9 Å.U., which are plainly seen in the photograph, are probably due to traces of gas impurities from the wax used with the quartz window. These bands did not appear in the other photographs taken with higher accelerating potentials, which was doubtless due to the much greater relative intensity of the argon arc. The fact that this radiation appeared with an accelerating potential of 10.1 volts, whereas the resonance potential has been found to be 11.5 volts,[6] is due to the initial energy of the electrons as they came out from the heated filament, for which no correction was made.

Plate I(*b*) shows a reproduction of the spectrum obtained with a grid voltage of 16 volts, which is approximately the ionization potential of argon. At this voltage a large number of lines, all belonging to the red argon spectrum appeared, the intensities of the various lines, of course, being somewhat different from the red spectrum produced by passing an induction coil discharge through an argon discharge tube, a reproduction of which is shown in Plate I(*c*). This agrees with the results of Déjardin and indicates that the red argon spectrum is due to the return of a single electron which has been removed by the bombarding electron moving with a speed corresponding to a fall in potential of 16 volts, or in other words, the red argon spectrum is produced by a recombination of a singly ionized argon atom with an electron. The photograph in Plate I(*d*) shows the mercury arc spectrum for wave-length comparison.

[6]Horton and Davies, loc. cit.

In Plate II are shown reproductions of photographs taken with accelerating voltages varying from 31 to 105 volts. Up to 30 volts potential on the grid only lines belonging to the red argon spectrum appeared. However at 31 volts some faint lines belonging to the blue or enhanced spectrum became evident (see Plate II(*a*)). As the voltage was increased these lines became more intense and others appeared as shown in Plate II(*b*), which was taken with a grid potential of 37 volts. Plate II(*c*) shows the spectrum of the arc when the accelerating potential was 40 volts, in which the number and intensities of the lines belonging to the blue spectrum were still further increased. These results do not exactly agree with those of Déjardin, who found that the lines of the enhanced spectrum did not appear until an accelerating potential of 34 volts was used. This discrepancy may be accounted for by the fact that in the present experiments the temperature of the filament may have been slightly greater than that used by Déjardin, which would mean that the bombarding electrons had a greater initial velocity and therefore required a smaller accelerating field to give them the same energy.

Plate II(*d*) shows the result with a grid potential of 54 volts. It is to be noted that, according to the Bohr theory, the potential necessary to give an impacting electron the required energy to remove both electrons from the helium atom is 54 volts. Hence the energy required to remove two electrons from any other neutral atom of higher atomic number than helium, is less than that corresponding to 54 volts owing to the repulsive force exerted by the remaining electrons. Thus with a grid potential of 54 volts all the lines of the enhanced spectrum of argon should be present. This would appear to be the case, as apart from changes in intensities, the spectrum was unchanged when a potential of 105 volts was used (see Plate II(*e*)). Some of the lines in the ultra-violet between the wave-lengths 2900 Å.U. and 2300 Å.U. are very faint and do not appear in the reproduction so that the agreement between the arc spectrum at 54 volts and the blue spark spectrum shown in Plate II (*f*) was much better than the reproductions would indicate. The spectrum in Plate II(*g*) is that of the mercury arc which, as before, was used for wave-length comparison purposes. It will be noted that the mercury line of wave-length 2536 Å.U. appears on several of the photographs, which was due to a trace of mercury vapour in the lamp.

V. *Conclusions*

The conclusions to be drawn from these results are necessarily somewhat indefinite. It seems clear, however, that with a speed corresponding to a fall in potential of about 31 volts a bombarding electron has sufficient energy to ionize the argon atom and to disturb a second electron to a certain degree. As the voltage is further increased the second electron is removed to a greater distance from the nucleus, but it is difficult to say at what voltage the atom is doubly ionized by the complete removal of two electrons.

There is also the possibility of removing more than two electrons from the atom and it was thought that a new type of spectrum might be brought out by increasing the accelerating potential. A photograph was taken with a grid voltage of 240 volts, but the results were negative as no new lines were brought out.

VI. *Summary*

1. The radiation produced in argon by electron bombardment with an accelerating potential of 10.1 volts has been detected photographically, and a table of wave-lengths is given.

2. With accelerating fields varying from 16 to 30 volts the lines in the arc spectrum were found to belong to the red argon spark spectrum.

3. As the grid potential was further increased to 31 volts the blue or enhanced spectrum began to appear. At 54 volts apparently all the lines in the enhanced spectrum were in evidence as predicted by the Bohr theory.

4. An attempt was made to bring on a third type of spectrum by use of a grid potential of 240 volts. The results of this experiment were negative as no new lines appeared.

B. *On the Absorption Spectrum of Argon*

I. *Introduction*

In a recent paper on the ionized spectrum of potassium, Professor McLennan[7] has shown that a moderate electrodeless discharge in potassium vapour produces a spectrum presumably due to the singly ionized atoms, which exhibits a striking similarity to the arc or red spectrum of argon. He has also shown that when potassium vapour is excited by a violent electrodeless discharge a new spectrum appears which resembles to a marked degree the enhanced or blue spectrum of argon. These experiments strongly support the theory suggested by Sommerfeld,[8] that the enhanced spectrum due to the singly ionized

[7]McLennan, Proc. Roy. Soc. A, Vol. 100, p. 182, 1921.

[8]Sommerfeld, Atombau und Spektrallinien, p. 296.

atoms of any element should resemble the ordinary or arc spectrum of the element immediately preceding it in the table of the elements. If the ionization of the atoms is such as to remove two electrons, according to this theory the spectrum due to the remaining system should resemble the enhanced spectrum of the immediately preceding element. This is a consequence of the theory that the outer electronic configuration of the ionized atom of any element whose atomic number is N, is the same as that of the neutral atom whose atomic number is $(N-1)$; and similarly that the arrangement of the outer electrons in the doubly ionized atom of atomic number N, is identical with that of the singly ionized atom of atomic number $(N-1)$, and also the neutral atom whose atomic number is $(N-2)$. This is readily seen from the diagrams of atomic models shown in Fig. 2.

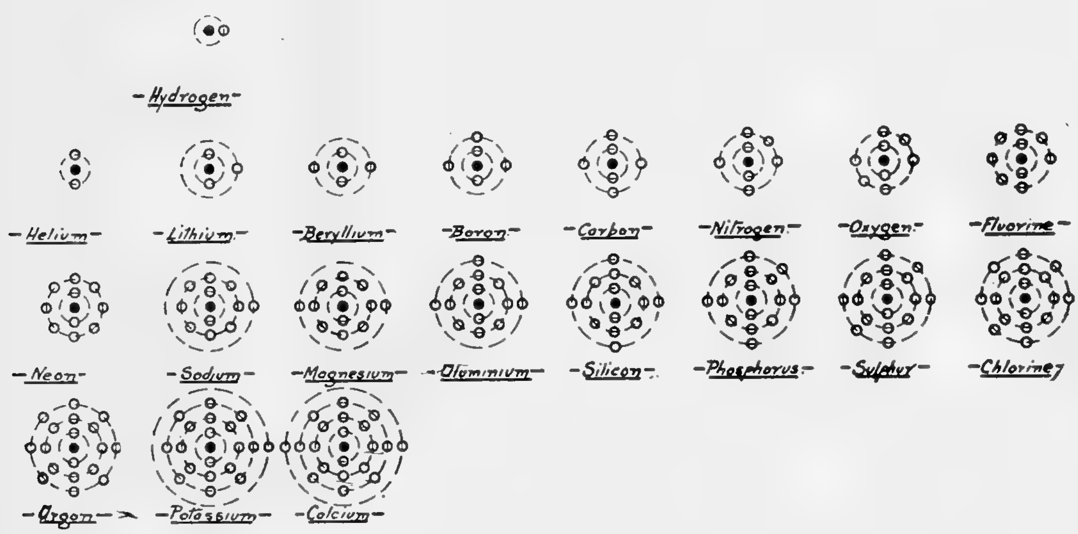


Fig. 2

The purpose of this investigation was to make a further test of Sommerfeld's prediction by comparing the absorption spectrum of argon in various states of ionization with that due to neutral and ionized atomic chlorine or sulphur, since chlorine and sulphur are the elements immediately preceding argon in the table of the elements. Accordingly a study has been made of the absorption spectrum of argon both neutral and ionized by various means, between the wave-lengths $\lambda=7000$ Å.U. and $\lambda=2150$ Å.U. In no case was a definite absorption observed either with the ionized gas or with the ordinary gas at a pressure of 102.4 atmospheres. Up to the present time the author has not investigated the absorption spectra of atomic chlorine and sulphur so that in this paper the experiments with argon alone are described. However, from the negative results obtained with ionized argon, it may be predicted on the basis of the Sommerfeld theory that neutral atomic chlorine should have a similarly transparent region, shifted slightly towards the infra-red on account of the smaller mass of the chlorine nucleus. Molecular chlorine has some well-known absorption bands in the visible region and it would be very interesting to see if these bands could be made to disappear by the disruption of the chlorine molecules into atoms. Further research is needed to determine this point.

II. *Experiments with Ionized Argon*

(*a*) The absorption tube consisted of a quartz tube 40.3 cm. long and 1.5 cm. in diameter, having clear quartz windows fused in at each end and two side tubes in which discharge terminals were sealed. The argon used was obtained as before by repeatedly passing a mixture of 80 per cent. argon and 20 per cent. nitrogen over turnings of calcium metal maintained at a temperature of 600°C. The absorption tube was thoroughly exhausted and then filled with purified argon gas at a pressure of 2 mm. of mercury. The light from the electric spark between aluminium terminals under distilled water[9] was focussed on the slit of the large quartz spectrograph used in the previous experiment and the absorption tube was placed in the path of the light between the focussing lens and the spectrograph slit. The gas in the absorption tube was feebly ionized by passing a weak discharge from a four volt induction coil between the discharge terminals in the side tubes. With the absorbing column of gas in this ionized condition the light from the discharge between the aluminium terminals under water was passed through the tube into the spectrograph and allowed to fall upon a Wratten panchromatic plate for one and three-quarters hours. The aluminium spark under water gave a beautifully continuous spectrum between the wave-lengths $\lambda = 7000$ Å.U. and $\lambda = 2150$ Å.U., but there was no evidence of any absorption whatever due to the ionized argon.

The experiment was repeated using as a source of radiation the blue argon discharge produced by passing the discharge from a condenser through an argon Geissler tube made of quartz. If the blue spectrum is due to a disturbance of electrons in the singly ionized atom, then argon gas, when feebly ionized, should be in a condition to absorb this blue radiation. The gas in the absorption tube was excited as before by a very weak discharge, so that it was in a feebly ionized condition. The time of exposure was one hour and forty minutes, but there was no indication of any absorption of the blue radiation.

[9]Henri, Phys. Zeit., No. 12, p. 516, June 15, 1913.

(*b*) The absorption tube was then re-exhausted and filled with pure argon at a pressure of 155 mm. of mercury. To produce ionization in the gas at this pressure necessitated a stronger discharge, so that in this experiment the discharge terminals in the absorption tube were connected in series with the argon discharge tube, which was again used as a source of radiation. A heavy condenser discharge was passed through the circuit, ionizing the gas in the absorption tube and at the same time giving the blue argon discharge in the Geissler tube. The light from the latter was passed through the absorption tube and brought to a focus on the slit of the spectrograph. The exposure in this case was twenty-five minutes but, as before, no definite absorption was observed.

This experiment was repeated, using a Tesla coil of heavy wire wound about the absorption tube to produce ionization of the gas. This coil was connected in series with the discharge tube and a strong Tesla discharge passed through the circuit. No absorption of the blue spectrum was detected with an exposure of thirty minutes.

(*c*) The tube was refilled with argon at a pressure of 5 mm. of mercury. Several experiments were performed similar to those previously described in an attempt to produce an absorption spectrum, but the results were again negative.

(*d*) A quartz bulb 6 cm. in diameter was filled with argon gas at a pressure which gave a brilliant glow when the bulb was placed in a coil through which a Tesla discharge was passing. The bulb was placed in the Tesla coil and mounted in front of the slit of the spectrograph. The coil was connected in series with the terminals of the quartz Geissler tube filled with argon and a Tesla discharge from a twenty volt induction coil passed through the circuit. The light from the blue discharge in the Geissler tube was passed through the quartz bulb and focused on the spectrograph slit. The time of exposure was sixteen minutes, but there was no indication of any absorption of the blue argon spectrum by the ionized gas in the bulb.

III. *Experiments with Argon at High Pressure*

The author has already investigated the absorption spectra of oxygen and nitrogen between the wave-lengths $\lambda = 7000$ Å.U. and $\lambda = 2150$ Å.U., and it was thought that it might prove interesting to examine the absorption spectrum of argon in this region. The absorption tube used and the arrangement of apparatus was precisely as in the experiments with oxygen and nitrogen, which have already been described in a previous paper.[10] The absorption chamber was

[10]Shaver, Trans. Roy. Soc. Can., p. 7, 1921.

a brass tube 35 cm. long and 1.5 cm. in diameter, having quartz windows 1.2 cm. in thickness securely held by brass caps screwed to the tube. The source of radiation was the spark between aluminium terminals under distilled water, which gave a continuous spectrum between the wave-lengths previously mentioned. The light from this spark was passed through the absorption tube filled with the gas and brought to a focus on the spectrograph slit.

The gas in the absorption chamber consisted of a mixture of 80 per cent. argon and 20 per cent. nitrogen at a pressure of 128 atmospheres and was obtained from the Canadian Sunbeam Lamp Company of Toronto. The equivalent argon pressure was 102.4 atmospheres, and as it was known from previous work that nitrogen at a pressure of 140 atmospheres was transparent in this region, the effect of the nitrogen in the tube was neglected. The photographic plates were Wratten panchromatic, as in the previous experiments and the time of exposure was one and three-quarters hours. There was no indication of any appreciable or visual absorption between the wave-lengths $\lambda = 7000$ Å.U. and $\lambda = 2150$ Å.U.

IV. *Summary*

1. The absorption spectrum of ionized argon gas at pressures of 155, 5, and 2 mm. of mercury has been investigated between the wave-lengths $\lambda = 7000$ Å.U. and $\lambda = 2150$ Å.U. No absorption was detected.

2. The absorption spectrum of argon gas at an equivalent pressure of 102.4 atmospheres has been studied in the same region. The gas at this pressure has been found to be transparent between the wave-lengths previously mentioned.

In conclusion the author wishes to express his sincere thanks to the members of the Advisory Council for Scientific Research, and particularly to Professor J. C. McLennan, F.R.S., who suggested these researches and under whose direction they were carried out. The author also desires to express his gratitude to Miss M. L. Clark, who assisted in the purification of the gas and in filling a number of the tubes.

Physical Laboratory,
University of Toronto.
May 15th, 1922.

PLATE 1

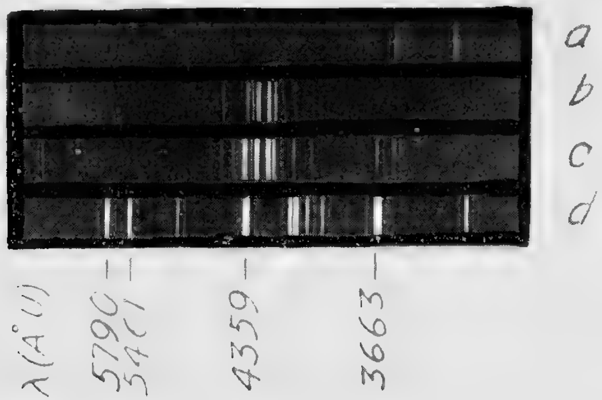
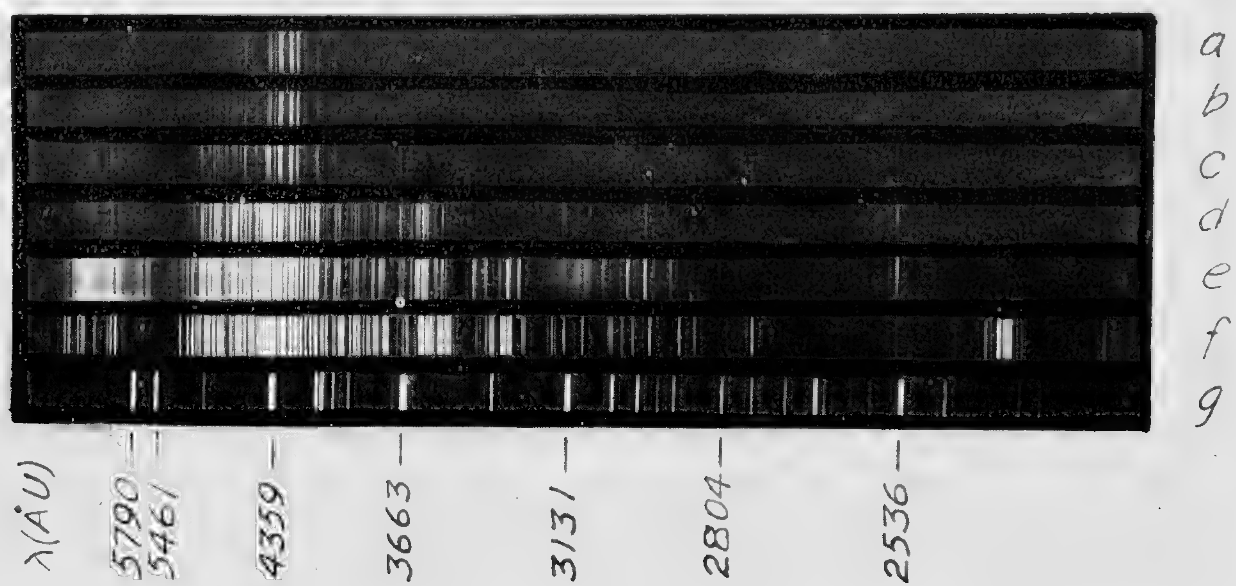


PLATE 2



On the Prism Method of Determining the Refractive Indices of Metallic Vapours

By H. G. SMITH, M.A.

(Read May Meeting, 1922)

An account has been given by Professor J. C. McLennan[1] of a new method of determining the refractive indices of metallic vapours by means of the deflection of a monochromatic beam of light, caused by a prism of the vapour enclosed between two quartz plates in a fused quartz tube.

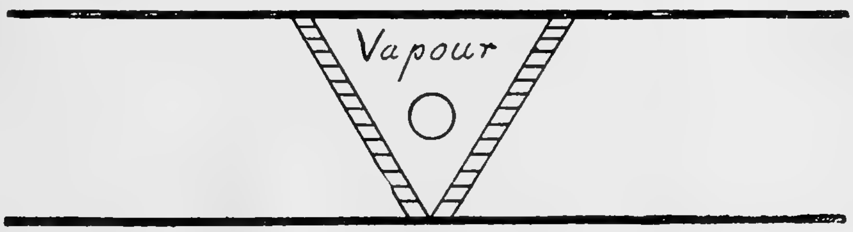


Fig. 1

A cross-section of one of these tubes is shown in Fig. 1. The oval plates were sealed into the tube at an angle as shown. A small quantity of the metal was placed in the space between them, and this space exhausted. An electric furnace was then built up around the entire tube. As made for the later experiments, the furnace gave a uniform and steady temperature up to 900°C., the variation being seldom more than 10° within an hour.

In the former account were also given some results obtained with Mercury vapour at about 300°C., and with Thallium vapour at about 450°C. These results for Mercury agreed moderately well with the results given by Cuthbertson and Metcalfe.[2] who used a Jamin refractometer. No attempt was made to determine the absolute refractivity of Thallium vapour, but relative values for light of different wave-lengths were obtained and a dispersion curve drawn.

It was recognized at this time that the quartz plates were slightly distorted, deflecting the light even when cold, and also altering the focus by a small amount. But, on account of the small temperature coefficient of quartz it was thought that the difference between cold

[1]Proc. Roy. Soc., Ser. A. 100, p. 191, 1921.
[2]Phil. Trans., Ser. A. 207, 1907.

and hot readings would give the effect due to vapour alone, within the probable error of readings.

In October of last year we commenced to repeat the experiment with Thallium, working at a higher temperature, about 800°C., and using a more accurate method of measuring the small deflections. This time we also expected to be able to determine the absolute refractivity. Great difficulty was experienced in obtaining a steady deflection at a higher temperature, and in repeating readings, either hot or cold, on successive days. However, values were finally decided upon, giving a dispersion curve of a somewhat similar shape to that previously obtained, but an absolute refractivity very different from our former estimate.

We next attempted to perform the experiment with Calcium, for which we expected to find a deflection just reasonably measurable, but obtained readings comparable with those for Thallium. It was now realised that the air in the ends of the tube might have a considerable effect on the deflection, and an experiment was commenced to determine the necessary correction. A carefully cleaned cell was highly exhausted, and the experiment performed with the empty cell under as nearly as possible the same conditions as before. The readings obtained for this correction were rather irregular, and were sometimes more, sometimes less, than those for Calcium, while they amounted to 60 to 75 per cent. of those for Thallium. It was obvious that no value could be attached to the corrected readings, even for Thallium, and a new tube was made with the object of eliminating the end effect.

A plate of quartz was chosen which deflected a beam of light not more than 3 or 4″, and which made no noticeable change in the focus. From this four plates were cut and sealed into a tube, as shown in Fig. 2. The intention was to evacuate the two end spaces and to

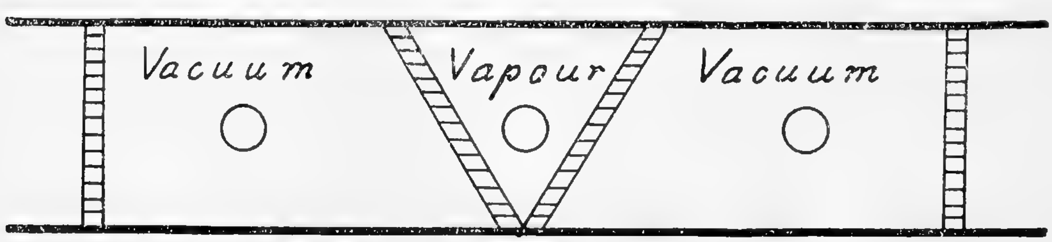


Fig. 2

place the metal in the centre space, but as a preliminary test all three spaces were exhausted.

It was found that after the plates were sealed in, the cold cell deflected the light about 50″. and the focus of the examining telescope had to be altered about 2 mm. On heating the cell to 800°C. a very considerable change in deflection took place, amounting in one instance to 30″. Thus the effect due to the quartz plates alone is comparable with the whole effect when filled with Thallium, which was from 50 to 90″, depending upon the source of light.

It was found also that at one given heating the deflection was very steady, and the probable error of the mean of 20 or more readings, taken at one heating, was never more than 0.3″, while readings taken on different days, both hot and cold, differed sometimes as much as 10″, and the differences between hot and cold readings correspondingly more.

The entire tube was then enclosed in an electric furnace and maintained at a brilliant red heat for 11 hours, in an attempt to anneal the plates. This caused no improvement whatever.

It was then decided that, while better agreement than that given above could probably be obtained, no reliance whatever could be placed on values which are the difference of two readings which are themselves unreliable within say 10 per cent. Consequently the method was abandoned.

Some mention should be made of the approximate agreement with other experimenters obtained in the case of Mercury vapour. The average temperature used in this case was about 320°C. as compared with 800°C., while the total deflection was somewhat greater, 2′ in some cases. Consequently the effect which has caused us to abandon the method is in this case comparatively small, and moderate agreement was obtained.

Refractive Indices of Metallic Vapours

2. *Interferometer Method*

The work outlined above is now being continued by means of a Jamin refractometer of a type designed by Michelson and first used by H. G. Gale[3]. The instrument was made by the workshop staff of the University of Toronto from blueprints furnished by Messrs. Hilger, who made the fluorite optical parts. Fig. 1 shows a plan of the instrument. The interference is obtained by means of the four fluorite mirrors *MM*, two half-silvered and two fully-silvered on the front surface. The two interfering beams, as shown in the figure, pass through tubes *T*, which may be filled with gas or vapour, then through the fluorite compensating plates *CC*, and are recombined in

[3]Phys. Rev. 14, Jan., 1902.

the telescope *U*. The source of light in use at present is a mercury lamp *S* used with various Wratten filters *F* to give a monochromatic beam. The source is at the focus of the lens *L*, so that a parallel beam passes through the instrument. The mirrors, the tubes, and the compensating plates are all mounted on soft bronze stands *D*, which can be moved between brass guides *BB*. There are two positions for the mirrors so that tubes of length 12″ or 33″ may be

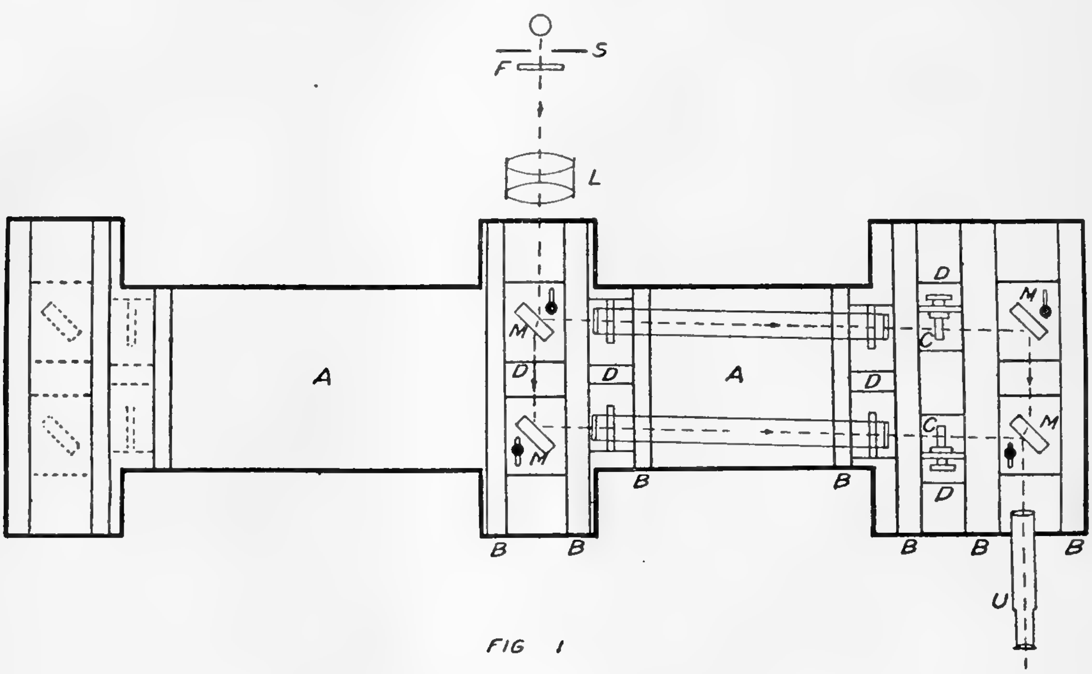


FIG 1

used. Fig. 2 shows in detail the stand which holds the mirrors. The mirror *D* is held in the bronze part *B* by a brass ring *C*. This part is held to the upright *A* by three screws *EE*, which with steel springs *FF* give a very fine adjustment of the mirror. The screw *G* is used to clamp the stand to the iron bed of the instrument.

For use with metallic vapours one tube is enclosed in an electric furnace as shown in Fig. 3. The tube *B* is made of fused quartz with quartz plates *AA* sealed in to it. The furnace of nichrome wire, insulated with asbestos, is built up around the tube, leaving the side piece projecting. The temperature is measured by thermocouples *DD*, and the windings are adjusted so that when a steady state is reached the ends are about 900°C. and the centre about 850°C.

Such a quantity of metal is used that it is entirely vapourized about 800°C., so that the density is known. Following the practice of Cuthbertson and Metcalfe[4] part of the tube, the small projection, is

[4]Phil. Trans. Ser. A. 207, Feb., 1907; Proc. Roy. Soc., Ser. A79, May, 1907; Proc. Roy. Soc., Ser. A80, May, 1908.

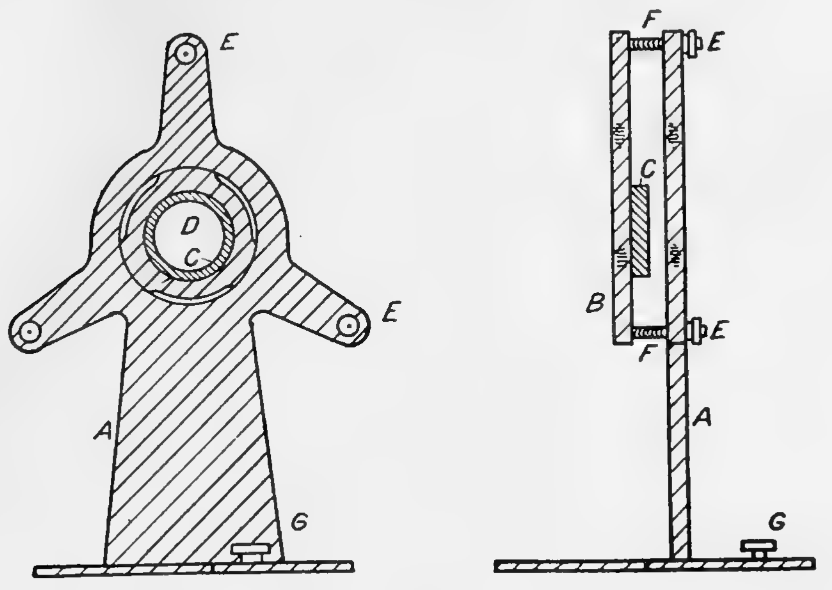


FIG. 2

kept cool by a wet rag or by a current of compressed air until the remainder reaches its final temperature. The metal all condenses here, and may then be entirely vapourized in a few minutes by a bunsen flame. Thus it is unnecessary to watch the fringes during the hour or more required to heat the furnace, and several readings may be taken at one heating.

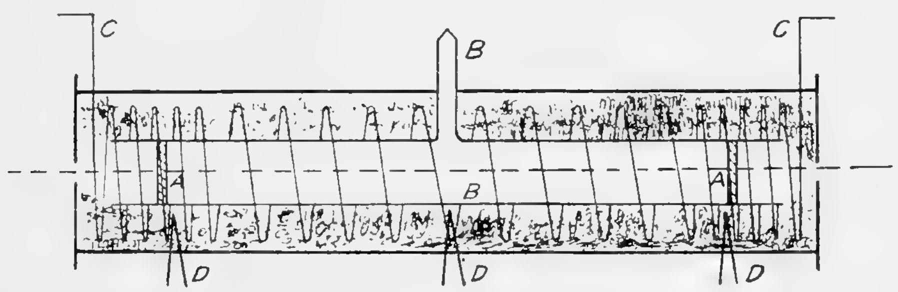


FIG 3

As the change is from vacuum to the given density the actual refractive index μ is given by

$$\mu - 1 = \frac{N\lambda}{l}$$

where N is the number of fringes counted, λ the wave-length and l the length of the tube.

If we define a standard density ρ_0 by the equation

$$\rho_0 = \frac{\text{Density of Hydrogen at } 0^\circ \text{ and } 76 \text{ cms.}}{\text{Molecular wt. of Hydrogen}} \times \text{Atomic weight of metal}$$

and if μ_0 is the refractive index for density ρ_0, and ρ is the actual density, then

$$\mu_0 - 1 = \frac{\rho_0}{\rho}(\mu - 1) = \frac{\rho_0}{\rho} \cdot \frac{N\lambda}{l}$$

Readings have been commenced with this apparatus, using Thallium metal, and results are expected to follow shortly. The few counts that have been made are consistent but no definite results can be reported yet.

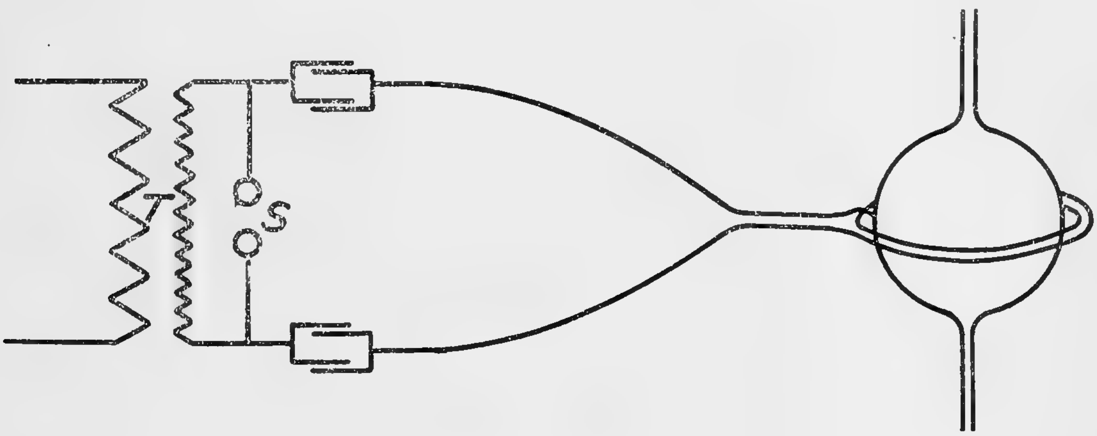
In conclusion, the writer wishes to thank Professor J. C. McLennan for suggesting this research and for helpful advice at all times. He also wishes to thank the Honorary Advisory Council for Scientific and Industrial Research for making it possible for him to undertake this research.

Physical Laboratory,
University of Toronto.
May 15th, 1922.

The Electrodeless Discharge in Iodine and in Hydrogen

By JOHN K. ROBERTSON

In a paper now in the press,[1] the writer has given results of a spectroscopic study of the discharge excited in certain vapours by electromagnetic induction. In the case of iodine, the only diatomic vapour studied, it was found that, as the electrical excitation was gradually increased, a stage was reached at which a sudden and marked change in the character of the discharge took place. It seemed desirable, therefore, to extend the investigation to other diatomic vapours and gases, and especially to hydrogen, whose complex secondary spectrum still awaits a satisfactory interpretation.



The experimental arrangement differed little from that first used by Sir J. J. Thomson. A bulb of capacity about 1 litre was suspended inside a coil of six co-planar turns of stout copper wire through which passed the high-frequency discharge of two "half-gallon" Leyden jars connected as shown in the diagram. The jars were charged by means of a small interrupterless X-ray transformer T, while the spark gap S enabled one to vary the intensity of the excitation. It is important to note that at any point within the ring the mean electrical intensity is directly proportional to the potential at the spark gap and independent of the capacity.[2] It is possible, therefore, by gradually lengthening the spark gap, to subject the gas or vapour to a steadily increasing electrical intensity and in this way study the change in the appearance of the discharge resulting from changing excitation.

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[1]J. K. Robertson, Phys. Rev. XIX 5 p. 470 May 1922.
[2]Bergen Davis, Phys. Rev. Vol. XX, p. 129, 1905.

Iodine

Before giving the results obtained with hydrogen it is desirable to refer briefly to those obtained with iodine. When a projecting stem of the bulb was immersed in a mixture of ice and water, it was found that two distinct types of ring discharge could be obtained. With a spark gap of the order of 1 mm. the ring had a pale yellow appearance, probably the same colour as the chamois yellow which Wood[3] describes. Examination with a spectroscope of small dispersion showed a continuous band extending from red to green, then a wide absorption band, followed by a second apparently continuous band in the blue-violet. As the spark gap was increased in length the appearance changed *abruptly* to a pale green ring with an inner border of pink. The spectrum of this second type of discharge showed numerous bright lines, with faint continuous background in the red region. The abrupt change in the appearance of the discharge is doubtless the result of dissociation, the pink border probably corresponding to the lesser degree of dissociation one might expect in the weaker electric field nearer the centre of the bulb. Observation with a small direct vision spectroscope directed successively at the green and at the pink portions of the ring showed that the lines in the pink were much feebler than in the green. This is what one would expect from a smaller degree of dissociation.

Hydrogen

Every precaution was taken to use pure, dry hydrogen. The gas, prepared electrolytically, was passed over hot copper, and for several days was in contact with phosphorus pentoxide before being admitted to the observation bulb. U-tubes, one on either side of the bulb, were immersed in liquid air, while the bulb itself was heated with the flame of a large Meker burner before the admission of hydrogen. In this way mercury, as well as water vapour, was excluded, although it should be stated that, on two of the three days on which observations were made, traces of mercury λ 5461 could be seen.

At pressures ranging from 0.3 to 0.1 mm. Hg. one readily obtained ring discharges, which, at any given pressure, changed with changing spark gap, in the following manner. Below a minimum gap, which was less, the lower the pressure, but of the order 1.3 mm. to 1.8 mm., no ring discharge was obtained. With increasing gap a whitish ring appeared, whose spectrum showed the secondary, feebly

[3]R. W. Wood, Researches in Physical Optics, Part II, p. 53, 1919.

developed, with traces of the Balmer lines $H\alpha$ and $H\beta$. On one occasion $H\alpha$ and $H\beta$ seemed to be absent, but as a rule, traces of these lines were visible at this whitish stage. As the gap was gradually lengthened, the whitish appearance gave way to a more and more pinkish shade, while, at the same time, both the Balmer lines and the secondary spectrum increased in intensity. With still greater excitation, the shade on the inner side of the ring deepened until at a certain stage (gap of the order of 7 mm.) the ring consisted of two portions, the inner a brick red, the outer pink. Photographs, which were taken with a two-prism Ladd spectrograph of small dispersion directed successively at the red and at the pink portions, gave evidence of the following: (1) Most of the secondary lines were relatively weaker in the red portion of the ring. In particular, the group of lines extending from a wave-length close to $H\alpha$ (λ 6563) to about λ 5680 were either absent altogether or extremely faint; while, with the exception of a strong line at λ 4928, lines between λ 5680 and $H\beta$ (λ 4861) were very faint. (2) The continuous background, which in all other photographs extended from about λ 4861 well into the violet, was absent. (3) On the other hand, a group of some 15 or 16 secondary lines running from λ 4316 (where there was a strong head) to λ 4136 came out as strongly in the photograph of the red portion as in that of the pink. Unfortunately, although the exposure given the "red" photograph was 23 minutes as compared with 18 minutes for the pink, the intensity of the former was somewhat weaker. But, while these statements are subject to some reservation on this account, the evidence points to the conclusions given. This will be evident from an inspection of the accompanying plate, where *a* is the spectrum of the red portion, *b* of the pink. The spectra are broken vertically because exposures were made with a neutral-tinted wedge before the slit, so placed that a part of the light passed below it, part above, the remainder through it.

The Blue Discharge

With conditions which gave rise to the red-pink ring it was noted that the whole of the region inside the ring had a distinctly bluish cast—a purple blue, not the blue so easily obtained when mercury vapour is present. The intensity of this luminosity was very feeble and no attempt was made to photograph its spectrum. That this glow is characteristic of hydrogen, however, there seems no doubt in view of some observations recorded by Masson[4] a few years ago.

[4] I. Masson, Nature, p. 503, Jan. 1, 1914.

Working with pure hydrogen excited also by electromagnetic induction, but with spark gap as long as 2 inches, and with pressures somewhat higher than those used by the writer, Masson obtained a rose ring showing both line and secondary spectrum, together with an inner blue zone whose spectrum showed nothing but lines.

It would seem, therefore, that in pure hydrogen four distinctly different coloured discharges are possible: (1) *whitish*, in which the Balmer lines are almost absent; (2) *pink*, in which both line and secondary spectra are strongly developed; (3) *red*, in which $H\alpha$ and $H\beta$ are relatively very strong and at least a portion of the secondary is absent; (4) *blue*, in which, according to Masson, the secondary is entirely absent and, moreover, $H\beta$ is stronger than $H\alpha$. Concerning this last appearance the writer will make further observations to see if Masson's results can be confirmed.

Discussion

The interpretation of these results is not easy. It is generally assumed that the Balmer lines have their origin in the atom, the secondary spectrum in the molecule. But the secondary spectrum is very complex. Fulcher,[5] for example, has shown that in the region approximately λ 6500-λ 5380 the lines may be divided into two groups, one of which is weak at feeble excitation, the other of equal intensity at feeble and at strong excitation. Merton,[6] too, has divided the many lined spectrum into three groups, the first of which is unchanged, the second enhanced, the third weakened, by the addition of helium to hydrogen. The writer's results indicate that in a region where the Balmer lines are relatively strong (a condition which is only obtained with strong excitation), a portion of the many lined spectrum, as well as the continuous background, is feeble or absent altogether, while another group of these (between λ 4316 and λ 4136) is strongly developed. If, now, we make the assumption to which little objection can be made, that the atom is the origin of the Balmer lines, this suggests that at least some of the lines of the secondary also may be associated with the atom. On the other hand, it is well to remember that in strongly excited gas we may have not only neutral atoms and molecules, but *ionized molecules*. Moreover, it has been shown by Franck[7] that the work of dissociation plus the ionization of an atom is less than the work required to ionize a molecule. Accordingly ionized molecules do not appear until the excita-

[5]G. S. Fulcher, Astrophy. Jour., Vol. 37, p. 60, 1913.
[6]Merton, Proc. Roy. Soc. A, 679, p. 382, Jan. 2, 1920.
[7]J. Franck, Phys. Zeit., No. 16, S. 466, 1921.

tion is tolerably strong and it may be that in them is found the origin of a portion of the secondary. But the problem is far from solution and one can only make suggestions and continue observations.

In regard to another point it has been difficult to give any explanation. It has been stated above that the red discharge (showing the Balmer lines relatively strongly developed) formed the inner portion of the discharge ring, the outer being pink. Now the expression[8] from which one may calculate the value of the electric intensity at any point within a coil of co-planar turns shows that the field is weaker nearer the centre of the coil. (Conditions, of course, are altered when a discharge takes place in the gas, but one may reasonably expect that the discharge region would have a shielding effect and, therefore, if anything, still further weaken the field at the centre.) Why is it, then, that the red discharge, which is evidence of an excess of atomic hydrogen, is on the *inner* portion of the ring? The question is all the more puzzling because in iodine, as noted above, the reverse was the case. The inner portion of the ring showed the lines less strongly developed as one would expect to be the case in the weaker field. The writer has no explanation to offer. It looks as if the walls of the bulb for some reason either made it easier for atoms to re-combine or made dissociation more difficult.* In this connection it is interesting to note that in Professor Wood's[9] paper on the spectra of hydrogen in long vacuum tubes a condition is described in which the tube showed a red discharge at the centre with a whitish appearance at the ends. There may, however, be no connection between the two cases.

The writer has under way further work and hopes to obtain more conclusive evidence regarding some of the questions raised.

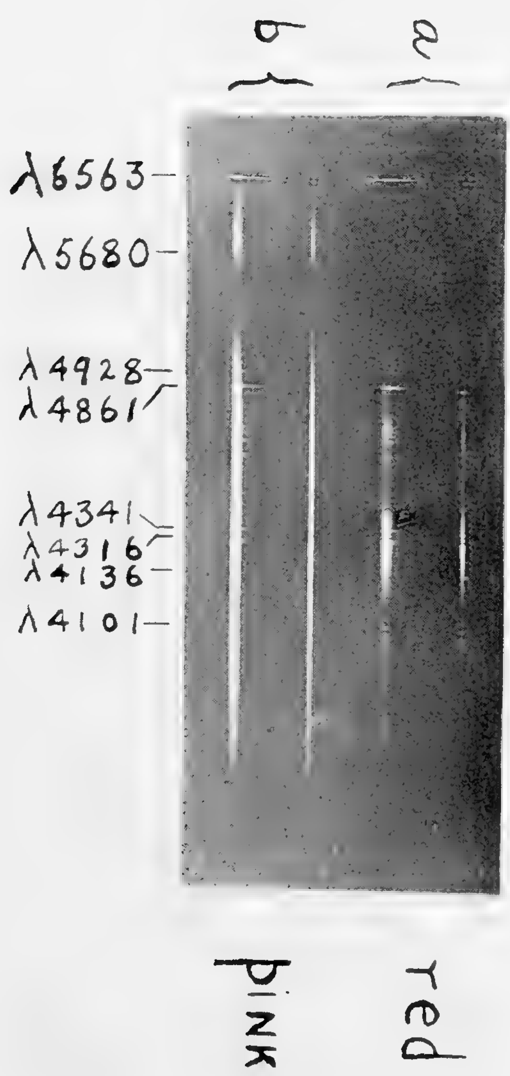
Queen's University.
June 8, 1922.

[8]Bergen Davis, loc. cit.

[9]R. W. Wood, Phil. Mag., Nov., 1921, p. 729.

*Note added September 14th, 1922:—

During the summer I have learned that according to Langmuir, there is much evidence to support the view that glass acts as a catalyser in promoting the combination of hydrogen atoms into molecules.


a
b
λ6563
λ5680
λ4928
λ4861
λ4341
λ4316
λ4136
λ4101
pink
red

Cavitation in the Propagation of Sound

By R. W. BOYLE

(Read May Meeting, 1922)

In the theory of the radiation of sound waves from a diaphragm or plate into a fluid medium, and also of the propagation of the waves through the medium, there enters a question as to whether the maximum amount of energy which can be transmitted is, or is not, limited by the phenomenon of cavitation.

For example, if a diaphragm in the medium is executing simple harmonic vibrations it pushes out into the medium and creates a compressional wave before it. When the diaphragm springs back on account of its elastic forces, if the static pressure of the medium at the surface of contact with the diaphragm is insufficient, the medium cannot *immediately* follow back with the diaphragm, which therefore *caves in*, away from the medium, producing thereby a vacuum or partial vacuum, and interrupting the rhythmic motion of the wave. The greater the static pressure of the medium, therefore, the greater will be the maximum possible amplitude of vibration, for any given pitch of vibration, to preserve the rhythmic character of the wave.

Again, in considering the travel of the wave through the medium, if at any point the amplitude of alternating pressure in the waves is p, and the static pressure there existing is p_o, the resultant pressure at the instants of maximum displacement is $p_o \pm p$. It might appear that p cannot exceed p_o, for if it did the resultant pressure at the instant of greatest rarefaction would be negative, i.e., the medium would be *under tension.* In this condition a discontinuity at that point in the medium might be produced, a vacuum or a bubble be formed, and the rhythmic character of the wave interrupted. In the case of solids cavitation of the kind above described could not occur.

At very low frequencies it is doubtless true that cavitation may be produced in the manner suggested, and therefore there will be a maximum amplitude of displacement corresponding to a given frequency at which energy can be transmitted in a regular wave motion. But there is a difference of opinion about such laws of cavitation remaining valid at higher ranges of frequency.

It is possible to demonstrate in very careful *static* experiments, that a liquid can be placed under a tension, but it is contended by some that in the dynamic case of wave motion it will not be possible for a tension in a fluid medium to exist, and that therefore cavitation will set an upper limit to the amount of energy which it is possible to transmit. On the other hand, others think that in the audible and higher ranges of frequency the vibrations are so rapid that there is not time for discontinuities to be formed in the medium, even if the alternating pressure in the wave exceeds the static pressure; that the medium can, during the time of half a vibration, be under a tension; and that with increasing rapidity of vibration the medium will behave more and more like an elastic jelly. Cavitation of the kind described above would therefore never be encountered.

In another connection Stokes made a remark which would seem to apply here: ". . . When a body is slowly moved to and fro in any gas, the gas behaves almost exactly like an incompressible fluid, and there is merely a local reciprocating motion of the gas from the anterior to the posterior region, and back again in the opposite phase of the body's motion, in which the region that had been anterior becomes posterior. If the rate of alternation of the body's motion be taken greater and greater, or, in other words, the periodic time less and less, the condensation and rarefaction of the gas, which, in the first instance, was utterly insensible, presently becomes sensible, and sound waves (or waves of the same nature in the case the periodic time be beyond the limits of audibility) are produced, and exist along with the local reciprocating flow. As the periodic time is diminished more and more of the encroachment of the vibrating body on the gas goes to produce a true sound wave, less and less a mere local reciprocating flow. . . ."[1]

If cavitation arising from a tension in the medium were to be encountered in a fluid, it is possible to calculate the maximum amplitude of displacement, at any frequency, for the transmission of energy and the maximum energy transmissible.

Let ρ = the density of the medium; c, the velocity of sound in it; f, the frequency; a, the amplitude of displacement; and p the amplitude of alternating pressure in the waves.

Then, considering only the case of plane waves, $\rho = 2\pi f \rho a c$, all quantities being in C.G.S. units.

If the static pressure of the medium at the point considered equals p_o, then if cavitation can take place p cannot exceed p_o.

Therefore the maximum amplitude for transmission, at the stated frequency f, is $\frac{p_o}{2\pi f \rho c}$, from which it can be seen that for any constant

[1]Stokes, Mathematical and Physical Papers, Vol. IV, p. 299.

static pressure in a given medium the maximum amplitude depends only on, and is inversely proportional to, the frequency.

Denote the energy propagated per second per square centimetre of wave front by W,

Then $W = \frac{1}{2}\rho(2\pi f)^2 a^2 c = \frac{1}{2}\frac{p^2}{\rho c}$

If p cannot exceed p_o, the maximum energy transmissible per square centimetre, per second is $W_m = \frac{1}{2}\frac{p_o^2}{\rho c}$

Hence the maximum energy per square centimetre per second would depend only on the static pressure in the medium and would be independent of the frequency.

In the case of the transmission of plane waves of sound in air at standard atmospheric pressure and fifteen degrees centigrade, $\rho = .00123$ gms. per c.c.; $c = 3.4 \times 10^4$ cms. per second; $p_o = 1.0 \times 10^6$ dynes per sq. cm. Therefore the maximum energy transmissible would be 1.2×10^{10} ergs per sq. cm. per sec., or 1.2 k.w. per sq. cm.

For various frequencies the maximum amplitude would be:

Frequency	Amplitude
15	256 cms.
50	77
150	26
500	7.7
1000	3.9
5000	0.77
20,000	0.019
50,000	0.077

These figures show that there is no possibility of cavitation being encountered in the transmission of sound waves in air. Long before the transmitted energy with vibration amplitudes of values like the above are possible, the waves would be interrupted and broken up by other causes. It has been pointed out by Stokes that in the theory of the propagation of waves of large amplitudes we must take into account that the condensations in the waves cannot, as in ordinary sound theory, be treated as infinitely small; and it is clear that a progressive wave of finite, very large, amplitude cannot be propagated without change of type [2] Discontinuities must occur on account of the more condensed portion of the wave gaining continually on the

[2]Stokes, Mathematical and Physical Papers, Vol. II, pp. 51-56.

portion less dense. "The wave becomes, so to speak, continually steeper in front, and slopes more gradually in the rear, until a time arrives at which the gradient at some point becomes infinite. After this stage the analysis ceases to have any real meaning." (Lamb).[3]

Considering cavitation of sound in water, e.g., sea-water, as in the case of under-water signalling:

$\rho=1.02$, and $c=1.5\times10^5$ cms. per second.

The maximum energies transmissible would depend on the depth at which transmission takes place, for the static pressure will increase as the depth increases. If P is the atmospheric pressure and d the depth, the maximum energy transmissible per sq. cm. per sec.

$$= \frac{1}{2}\,\frac{(P+\rho d)^2}{\rho c} \text{ ergs,}$$

and the maximum amplitude, at frequency f, $=\dfrac{P+\rho d}{2\pi f\rho c}$ cms.

Depth from surface	Pressure in dynes per sq. cm.	Maximum energy transmissible
0 metres	1.01×10^6	4.5 H.P. per sq. metre or 0.34 watts per sq. cm.
3 "	$(1.01+0.3)\times10^6$	0.56 " " " "
6 "	$(1.01+0.6)\times10^6$	0.85 " " " "
12 "	$(1.01+1.2)\times10^6$	1.59 " " " "

Frequency	Maximum amplitude for transmission			
	0 metres depth	3 metres depth	6 metres depth	12 metres depth
15	0.070 cms.	0.091 cms.	0.112 cms.	0.153 cms.
50	0.021	0.027	0.034	0.046
500	0.0021	0.0027	0.0034	0.0046
5,000	0.00021	0.00027	0.00034	0.00046
50,000	0.000021	0.000027	0.000034	0.000046

These formulae and figures indicate clearly that in the case of the transmission of sound through liquids it might occur that cavitation of the kind here discussed would limit the power of transmission, and therefore it would follow that the deeper the radiating source was immersed the greater would be the amount of energy transmissible. When the maximum of energy transmission at a given depth had been reached, the only means then of increasing the radiating power would be to increase the emitting surface of the radiator.

[3]Lamb, Dynamical Theory of Sound, para. 63.

The point raised in this paper should be tested experimentally for final settlement, but unfortunately we have no practical cases where the emission of energy is great enough for this phenomenon of cavitation to intervene.

In air, King[4] has measured approximately the energy emission from a modern diaphone used as a fog-alarm, and found at the greatest emission, under the best conditions, an energy flux of 2.36 H.P. for 14 sq. inches of surface in the trumpet of the instrument. This is a rate of only 19.5 watt per sq. cm., which is much too small for any test of the kind required here.

Fessenden[5] has asserted concerning the Fessenden submarine oscillator that operating at a frequency of 500 ~/sec. there would be no difficulty by suitable design in obtaining 35 H.P. delivered to the water. If the diaphragm of such an instrument had a radiating surface of twenty inches diameter, as in the case of the ordinary Fessenden oscillator, this emission of energy would correspond to a rate of 17.3 watts per sq. cm. As shown by the tabulated figures above this would be about ten times the rate of energy propagation required to test the question of cavitation, but no such energy emissions in water have been accomplished practically. In some cases of the use of a Fessenden oscillator the sound energies emitted in the water were found to be about 350 watts at a frequency of 300 ~/sec., and 500 watts at a frequency of 540 ~/sec. For a twenty-inch diameter diaphragm these emissions correspond to rates of 0.017 and 0.025 watts per sq. cm., respectively. The figures tabulated above show that rates fifty times greater would be required to test for cavitation as here described.

The writer has recently experimented with an energy emission of about 0.09 watts per sq. cm. of radiator surface, but this rate of emission would have to be increased five times before any hope of testing this cavitation experimentally could be entertained.

The above figures of practical sound production illustrate how difficult it is to transform large amounts of energy into actual sound waves, and that all apparatus for sound production must be "inefficient" in the scientific sense.

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[4]Acoustic Efficiency of Fog-Signal Machinery, Phil. Trans. A, Vol. 218, pages 211-293.

[5]Fessenden, Long-Distance Submarine Signalling, Lawrence Scientific Ass., June, 1914, p. 15.

High Frequency Vibrations, and Elastic Modulus of Metal Bars

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(Presented by R. W. BOYLE, F.R.S.C.

(Read May Meeting, 1922)

A method which could be adopted to obtain the velocity of a compressional wave and Young's elastic modulus of a metal bar is that based on the device known as "Kundt's Tube." A rod of the metal, a meter or so long, is clamped firmly at its central point, and one end bears a light disc of thin metal which extends across without touching a long glass tube. The opposite end of the tube is closed by a similar disc, the position of which is adjustable, and in the bottom of the tube a very little powder of lycopodium seed is scattered from end to end. If the end of the steel rod remote from the glass tube be now stroked with a piece of chamois skin covered with powdered resin a note of high frequency will be emitted by the rod, and, if the adjustable disc be properly placed, standing waves are formed in the air in the glass tube, the nodes and loops of which register in the dust in the tube. A very simple calculation is all that is necessary to obtain the velocity of the wave in the metal rod and Young's modulus for the rod.

The purpose of this paper is to describe an even simpler method for arriving at the same results, which appears to the author to have certain advantages over the method devised by Kundt. For example a steel bar, 2.54 cms. in diameter and 30 cms. long, was firmly clamped at its middle point by a special, tempered, steel clamp, in which the actual surface bearing upon the bar was only about 2 mm wide and fitted into a shallow groove cut around the bar at this point. This clamp made it possible to fix the steel bar rigidly to a stone table. (See diagram.) Opposite one end of the

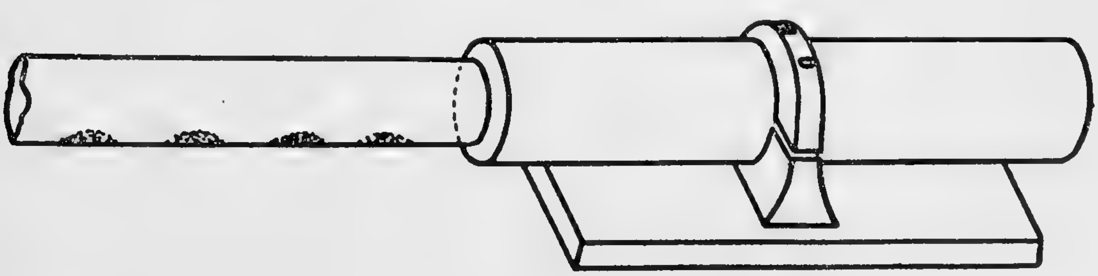


Fig. 1

metal bar, but on an entirely separate support, a glass tube, of 1.4 cms. internal diameter, was fixed in such a position that the longitudinal axes of the bar and the tube were approximately coincident, but the end of the tube was separated by a few millimetres from the end of the bar. The end of the glass tube remote from the bar was closed by an adjustable plug of metal, and a little lycopodium powder was scattered throughout the length of the tube. On striking the end of the metal bar farthest from the tube a smart blow with a hammer it was found that dust figures were very easily produced in the tube.

It may be well to point out here what are the advantages in this modification over the method previously indicated. In the first place the apparatus is a little simpler, involving as it does merely a short length of a round bar of the metal with a shallow groove at the central point. Lengths have been used as short as two inches. But a more important advantage is the fact that it is much easier to obtain the dust figures with this apparatus. One blow of the hammer is usually sufficient to produce a train of the figures a metre or more long. Furthermore, the method is admirably adapted to high frequency vibrations, a frequency as high as 50,000 per second having been attained. Such use cannot, of course, be made of Kundt's apparatus. Finally the latter method has one marked defect. One is never sure of the exact temperature of the metal rod at the time when the dust figures are formed because the stroking with the chamois, even though but a few strokes are necessary, quickly raises the temperature of the rod to some unknown value.

The theory of the free longitudinal vibrations of a bar, where the damping can be neglected or, as in the present case, the damping is not sufficiently great to have an appreciable influence on the period, leads to the equation of motion

$$\frac{d^2y}{dt^2} = C^2 \frac{d^2y}{dx^2}, \text{ where } C^2 = \frac{E}{\rho}$$ [1]

Here y represents the displacement at the time t of a plane perpendicular to the axis of the bar whose undisturbed position is at a distance x from the origin; E is Young's modulus for the material of the bar, and ρ is its density.

To find the normal modes of vibration it is usual to assume that y varies as $\cos(nt+\epsilon)$ so that the equation becomes

$$\frac{d^2y}{dx^2} + \frac{n^2}{c^2} y = 0$$

[1]Raleigh, "Theory of Sound," Vol. 1, page 245.

The solution of which is

$$y=\left(A\cos\frac{nx}{c}+B\sin\frac{nx}{c}\right)\cos(nt+\epsilon),$$

where A and B are constants depending upon boundary conditions. Thus if the origin is taken at one end of the bar then

$$\frac{dy}{dx}=o \text{ for } x=o \text{ and } x=l,$$

where l is the length of the bar. So that $B=o$ and

$$\sin\frac{nl}{c}=o \text{ or } \frac{nl}{c}=s\pi$$

where s has all integral values including zero.

The frequency $N=\frac{n}{2\pi}$ so that we have $N=\frac{sc}{2l}$, or the frequency varies inversely as the length of the bar if the velocity c is constant, and the frequencies of the various modes may be calculated by giving s its integral values.

The nodes $(y=o)$ are given by those values of x which make $\cos\left(\frac{s\pi x}{l}\right)=o$. The gravest node $(s=1)$ gives, therefore, a node at the centre and we see that a bar clamped at its central point is capable of free vibrations. The only mode dealt with in this work is that corresponding to $s=1$ but for bars longer than one meter evidence of vibrations corresponding to the nodes $(s=2)$ was also found.

Turning now to a discussion of the stationary waves in the air in the glass tube we see that for free vibrations of the air column exactly the same mathematical relation would apply, provided that both ends of the tube were open. There would be a node of displacement at the centre of the tube.

If both ends are closed the boundary conditions lead to the formation of a node at each end only, for the gravest mode.

However, in the arrangement under discussion, while the vibration of the bar is free, at least after the first few oscillations, the air column vibration is never free, but is due to an impressed force of the form $y=A\cos(nt+\epsilon)$ situated at $x=0$. If the tube be closed at $x=l$ the motion of the gas will be given by

$$y=\frac{A}{\sin\frac{nl}{c}}\sin\frac{n(l-x)}{c}\cos(nt+\epsilon,)$$

where the symbols are as before.

The amplitude becomes very great when $\sin\frac{nl}{c} = o$ or $\frac{nl}{c} = m\pi$ where m has all integral values. Or since $c = N\lambda$ *and* $N = \frac{n}{2\pi}$ resonance occurs when $l=\frac{1}{2}m\lambda$ where m is integral. The reflector must, therefore, be placed in the tube to accord with this condition.

As in Kundt's method, the end of the bar is the exciting source for the air waves, and therefore the same method of measurement regarding the vibration of the bar from the vibration of the air column will apply. In other words if the stopped end be placed so that $l=\frac{1}{2}\,m\lambda$ the nodes are formed in the dust in the tube at the positions $x=o$, $x=\frac{\lambda}{2}$, $x=\lambda$, etc., so that the distance between two successive nodes is one half the wave length. Hence, recalling that the total length of the bar is one half the wave length in the metal, we may find the velocity of the wave in the metal from the velocity of the wave in the tube by multiplying the latter by the ratio of the length of bar to the distance between nodes in the tube.

The following table gives a typical set of readings. The bar used was of soft cast steel, 2.54 cms. in diameter and 30 cms. long. The glass tube was 1.4 cms. internal diameter.

No. of vibrating segments measured.	Distance over the segments	Temperature °C.
30	59.5	18.7
30	59.5	18.6
30	59.5	18.5
30	59.5	18.2
30	59.5	18.2
30	59.4	18.2
30	59.5	18.2
30	59.5	18.2
30	59.4	18.2
30	59.5	18.3

These values give the wave lengths of the air wave in the tube as 11.9 cms. and the frequency of vibration of the bar 8580 per second.

The velocity of the air waves in the tube which was used here is not the same as the velocity of sound in free air. In consequence, the results obtained by Blaikley[2] for the velocity of air waves in a

[2]Phil. Mag. 1884.

tube were used. These results give the velocity of air waves at moderate frequencies in a smooth brass tube of 1.4 cms. diameter as 325.6 meters per second at O°C.

Correcting this velocity in the tube for the temperature of the room as given in the table the velocity of the wave in the steel bar was found to be 5090 meters per second at 18.2°C. Using Newton's equation for velocity we obtain the value $E=2.15\times10^{12}$ dynes per square cm. for Young's modulus for the steel.

The possible error in this result cannot be stated definitely since the error in Blaikley's results is not known; but aside from this, which is not vital in any case, it is clear that the error in the length of the bar need not exceed 0.1% and in the density 0.1%. In estimating the error in the distance between two successive nodes in the dust figures it may be stated that this may be made very small by measuring a large number of the vibrating segments. It was found practicable to employ a tube 150 cms. long and measurements were taken over 30 vibrating segments. Estimating the error, then, in this distance as say 0.15% gives the possible error in E as approximately 0.7% or the modulus is given to the third significant figure.

It might be questioned whether the velocity obtained for the waves in the steel bar is really that corresponding to the equation $V=\sqrt{\frac{E}{\rho}}$ when E is simply Young's modulus, or whether the lateral contraction operates to alter this velocity by introducing a factor corresponding to rigidity. Rayleigh[3] has investigated this point and finds that the lateral inertia operates to increase the natural period, i.e. to decrease the natural frequency in the ratio:

$$\frac{1}{1+\frac{i^2\sigma^2\pi^2r^2}{4l^2}}$$

where σ is Poisson's ratio, r is radius of bar, l is its length and i is integral and corresponds to the modes of vibration.

If we take r equal 1 inch and l equal 10 inches, and i equal 1, and σ equal to 0.31, we find that the ratio obtained is 1:1.0000435. Therefore, in the present case, the lateral effect is insignificant and need not be considered.

The question as to whether the air waves are affected by the yielding of the walls of the glass tube was also investigated. The potential energy corresponding to a given strain $\frac{dy}{dx}$ of the fluid in

[3]Rayleigh, "Theory of Sound, Vol. 1, pages 251-3.

the tube is diminished and the wave velocity is therefore lowered. Lamb[4] gives the following data. If the theoretical velocity of the waves in the fluid is C_o and the actual velocity C these velocities are related in a tube of thickness h as follows:

$$C^2 = \frac{C_o^2}{1 + \frac{2\,K\,a}{h\,E}}$$

Where a is the internal radius; K the volume elasticity of the fluid, and E Young's modulus for the material of the tube.

Since K for air has the value 10^6 and E for glass is 6.03×10^{11}, we see that for a glass wall 1mm. thick and 1.4 cms. diameter, the squares of the velocities have the ratio 1:1.0000232. Therefore this effect also need not be considered as affecting results.

A Test for Hardness

An investigation was made to see if this method might be used as a means for testing the hardness of steel. Another set of readings was taken with the identical bar used for the first table but this time the bar was hardened by slowly heating and quenching in cold water. The bar was used in this dead hard state without drawing the temper.

It was found that the distance between successive loops had increased from 59.5 cms. for 30 loops before tempering the bar to 60.2 cms. for 30 loops after tempering; i.e. from 1.98 cms. to 2.01 cms. This gives a change in the value of Young's modulus due to tempering from 2.15×10^{12} dynes per square cm. to 2.09×10^{12} dynes per square cm., or about 3%.

Static and Dynamic Moduli

It was suggested by Rayleigh[5] that it was probable that the value of Young's modulus for a metal as found by a static method would be somewhat different from that which corresponded to a dynamical condition such as prevails in the propagation of sound. The variation would depend on the difference, if any, between the isothermal and adiabatic elasticities of the metal. In solids this difference is inappreciable. Kelvin[6] has calculated the value of the ratio of the dynamic to the static moduli of elasticity, and finds it to be

[4]Lamb, Dynamical Theory of Sound, p. 173.
[5]Rayleigh, Theory of Sound, Vol. 1, p. 246.
[6]Kelvin, Encyclopedia Britannica, New Werner Edition, Vol. VII, Article on "Elasticity."

$$\frac{M^1}{M} = \frac{1}{1 - \frac{Te^2 M}{JK\rho}}$$

where M^1 denotes the dynamical and M the static value of Young's modulus, T the absolute temperature, J Joule's equivalent, e the strain produced by an elevation of temperature by 1° while the body is under constant stress, K the specific heat under constant stress, and ρ the density. The value of the ratio $\frac{M^1}{M}$ for iron on this basis works out as 1.0026.

Wertheim[7], as long ago as 1848, by the methods then prevailing measured the static and dynamic moduli of metal wires, the former by the method of direct elongation, and the latter by transverse and longitudinal vibrations. Examples of his results are the following:

Copper wire—drawn—Young's modulus, by	direct elongation,	1.245 x 10^9 gms. sq. cm.
	trans. vibration,	1.251 gms. sq. cm.
	longit. ,,	1.254 gms. sq. cm.
Copper wire—annealed " " "	Direct elongation,	1.052 gms. sq. cm.
	trans. vibration,	1.183 gms. sq. cm.
	longit. "	1.254 gms. sq. cm.
Silver—drawn " " "	direct elongation,	0.736 gms. sq. cm.
	trans. vibration,	0.782 gms. sq. cm.
	longit. "	0.758 gms. sq. cm.
Steel—drawn " " "	direct elongation,	1.881 gms. sq. cm.
	trans. vibration,	2.071 gms. sq. cm.
	longit. "	1.994 gms. sq. cm.

In the propagation of elastic waves through a metal, a quite low frequency of vibration should be sufficient to ensure that this process is entirely adiabatic, so that on this score no change should be expected in the modulus of elasticity and therefore in the velocity of propagation as the frequency increased up to very high values. By the method described in this paper this point was investigated up to a frequency of 50,000 vibrations per second by using steel and brass rods to a shortness of 5 cms. Following are two tables of values, I. and II., the first derived from steel bars ranging in length from 200 to 5 cms., and the second for brass bars of length 30 to 5 cms. It can be seen from both these tables that the velocity

[7]Wertheim. Ann. de Chimie, 1848.

does not change at these high frequencies within the limits of experimental error. More than one reading was taken for each length of bar, but space does not permit the publication of all of these values, as the observations did not differ by more than one millimeter in total distance measured.

TABLE I.

Length of bar in cms.	No. of vibrating segments measured	Dist. in cms. over segments measured	Temp. °C.	Av. Dist. between nodes in cms.	Vel. of wave in air, cms. per sec.	Frequency per sec.	Velocity in steel, meters per sec.
200	7	92.7	22.8	13.24	339.3	1280	5125
150	10	98.6	18.6	9.85	336.8	1710	5130
100	15	99.0	20.5	6.60	337.7	2555	5110
80	18	95.5	23.0	5.30	339.4	3204	5125
60	25	98.5	19.5	3.94	337.3	4283	5140
40	37	97.9	21.4	2.65	338.5	6385	5110
30	50	99.3	24.1	1.98	340	8580	5150
25	60	100.0	24.1	1.66	340	10240	5120
20	71	95.0	24.3	1.35	340.2	12800	5065
15	83	82.7	24.5	1.00	340.3	17150	5145
10	79	53.3	25.2	.67	340.7	25900	5180
5	19	6.6	25.8	.34	341.1	50150	5015

TABLE II.

Length of bar in cms.	No. of vibrating segments measured	Dist. in cms. over segments measured	Temp. °C.	Av. Dist. between nodes in cms.	Vel. of wave in air, cms. per sec.	Frequency per sec	Velocity in steel, meters per sec.
30	33	97.7	23.0	2.96	339.4	5730	3439
25	31	76.5	25.8	2.47	341.1	6900	3452
20	48	94.0	24.2	1.95	340.1	8715	3486
15	67	98.9	24.2	1.47	340.1	11560	3470
10	52	51.2	25.8	0.99	341.1	17225	3445
5	28	13.9	23.0	0.50	339.4	33940	3395

The curve, figure 2, which gives the relation between the wave-length in the metal (twice the length of the bar) and the wave-length in the tube, shows that this relation is strictly linear. This means really that the ratio of the velocities of these longitudinal elastic vibrations in metal and in air remains constant through the range of these high frequencies; if one changes, the other changes in the same ratio. Since it is highly improbable that the velocity in air changes at all, we may take it as a result that the velocities in metals and air remain constant at the high frequencies and, as already indicated, are the same as in the ordinary frequency range.

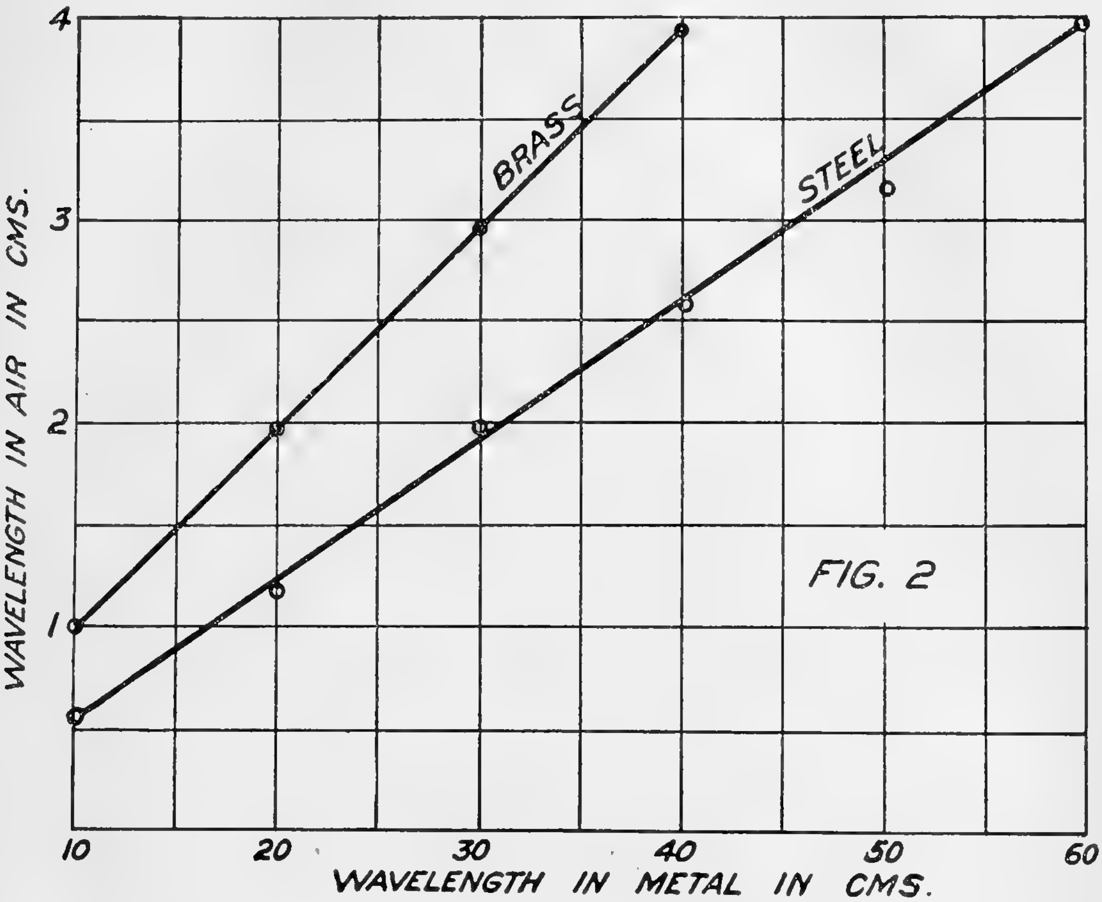


FIG. 2

DAMPING

On the question as to whether the damping by "solid viscosity" affects the velocity in these metal rods, the evidence here is that up to a frequency of 50,000 vibrations per second the damping is not sufficient to affect the velocity of the natural period appreciably. Cady[8] points out that the true velocity (c) is given by the relation

$$C = \sqrt{C_0 - \frac{Qk^2}{4}}$$

where C_0 is the velocity given by $\sqrt{\frac{E}{\rho}}$, $K = \frac{2\pi}{\lambda}$,

λ being the wave length, and Q a factor depending on the "solid viscosity." There is no value for Q yet quoted.

In attempting to obtain the dust figures for these bars ranging from 200 cms. to 5 cms. in length a matter arose which should be

[8]Theory of Logitudinal Vibrations of Viscous Rods, Phys. Rev., Jan., 1922.

mentioned. First, in using long bars the dust figures showed the presence of overtones quite markedly and the nature of these confirmed the theory of nodes and loops in the vibrating bar as advanced above.

Secondly, for very short bars, ten cms. and less, it was found very difficult at first to get any effect. The explanation was sought in the theory of impact. The classical theory of impact, based upon the theory of the compressional waves in the bar and the hammer being reflected from the distant ends as tension waves and thrusting the two pieces apart, is given in Thomson and Tait: Treatise on Natural Philosophy, Part 2, pp. 228-229. If the hammer be short compared with the length of the bar, it should be possible to cause the hammer to rebound so as to allow the bar to vibrate freely and produce the standing air waves in the tube. The size of the hammer permissible can be calculated and this was done, but the hammer produced was not a success. It was found that a very much smaller hammer with a slender handle was required. A paper recently published by Tschudi[9] bears on this question. By a very precise experimental method the author shows that the compressional wave theory of impact does not hold, but that the theory advanced by Hertz[10] better represents the facts for the duration of impact of spherical bodies and also for cylinders. This theory is based on the local effect of the pressure, which seems to explain how the end of a bar becomes "upset" under the blows of the hammer. Of course the compressional waves also pass through the bar and are reflected from the ends as well.

It must be pointed out that the air waves arising from a vibrating disc such as the end of one of these bars do not move out in a spherical form if the frequency is great, but in the form of a beam whose boundary makes an angle ϕ with the normal to the disc through its centre given by the relation $\sin\phi = 1.22\frac{\lambda}{D}$ where D is the diameter of the disc and λ is the wave length of the air waves produced. The angle ϕ for a bar of 2.54 cms. diameter and 5 cms. long is 17° approx.

Also, it can be shown that on account of wave interference, effects occur in the medium immediately in front of the disc resulting in places of maximum and minimum intensity along the projected axis of the bar.

[9]Duration of Impact of Bars. Physical Review, p. 423, Jan., 1922.
[10]Miscellaneous Papers. p. 146, 1896.

The distance d of these regions of maximum and minimum disturbance from the disc is given approximately by

$$d = \left(\frac{k^2}{n} - \frac{n}{4}\right)\lambda$$

where the constant K is defined by the relation $R = k\lambda$, R and λ being defined as above, and n has all integral values commencing at unity.

The odd values of n determine the distances to the successive maxima, and the even values of n to the successive minima, commencing with the farthest from the disc. Thus the farthest point of minimum disturbance ($n = 2$) is found to be at a distance of 3.1 cms. from the end of the bar 5 cms. in length and 2.54 in diameter.

Both of these effects just discussed must be kept in mind in using this method for the study of high frequency vibrations, but they need not affect the results of such measurements as are given here if the loops are measured a short distance away from the end of the tube.

The experiments here described have been found very suitable as a laboratory experiment for students, and are now used in this laboratory.

In conclusion, my thanks are due to Prof. Boyle, who suggested this research and kindly followed its progress.

Physical Laboratory,
University of Alberta.

The Reduction of Iron Ores by Carbon Monoxide

By ALFRED STANSFIELD, D.Sc., F.R.S.C., and DONALD R. HARRISON, M.Sc.

(Read May Meeting, 1922)

The research described in this paper[1] is a preliminary study of the rate at which hematite and magnetite ores can be reduced to the metallic state by heating the crushed ore in a stream of carbon monoxide to temperatures between 700°C. and 950°C. One ore employed was a pure dense hematite from Lake Superior containing 68 per cent. of iron and 2.9 per cent. of silica and alumina. The other was a magnetically concentrated magnetite from Hull, Que., containing 57 per cent. of iron and 15.7 per cent. of insoluble matter. Each ore was crushed and passed through a sieve of 30 meshes to the linear inch, the finer particles passing through a sieve with 40 meshes to the inch, were rejected. The ore particles employed were thus nearly uniform in size and measured about 0.5 mm. in diameter. The ore, spread out in a boat, was heated in a silica tube in an electric tube-furnace, and a stream of carbon monoxide was passed steadily over the ore. The quantity of ore used was 2.5 grams in most of the experiments, this amount, which was needed for the chemical analyses, formed a layer of 2 mm. or about 5 grains of ore in depth.

When the furnace had been heated to the desired temperature carbon monoxide was admitted to one end of the silica tube. The gas leaving the other end of the tube was measured and analyzed for carbon dioxide. The extent to which the ore had been reduced to the metallic state was found by the loss of weight of the ore in the boat, by analysis of the reduced ore and by the amount of carbon dioxide formed. These independent methods were found to check very well and it was therefore possible to calculate the amount of oxygen remaining in the ore, at each stage, from the amount of carbon dioxide formed up to that point.

A chart was plotted for each experiment, showing on a time basis the amount of oxygen in the ore and the amount of carbon dioxide in the gas. As an example of these, Fig. 1 shows the reduction of the hematite ore at 850°C. in a stream of 1500 c.c. per hour of carbon monoxide. The "percentage reduction" referred to in the chart represents the loss of oxygen from the ore expressed as a percentage of the amount originally present.

[1]The experiments were made by D. R. Harrison as thesis for his M.Sc. degree.

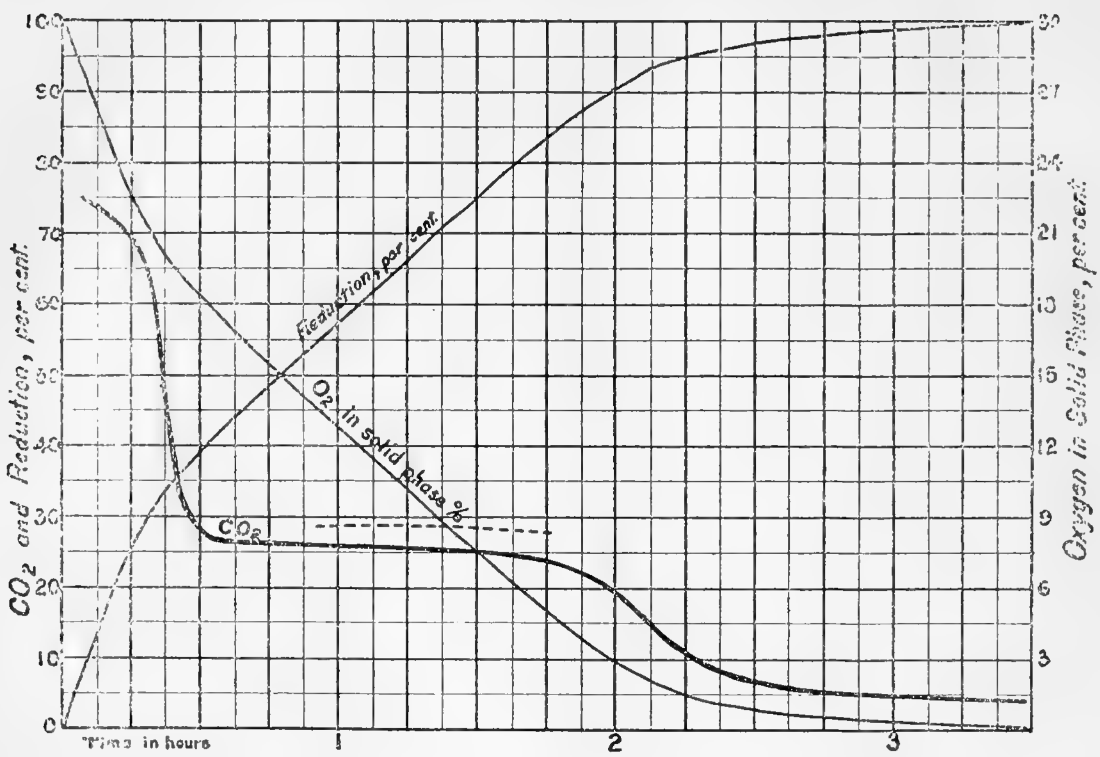


Fig. 1. Rate of Reduction of Hematite in Carbon Monoxide at 850°C.

The peculiar stepped nature of the curves indicates the different stages of reduction, thus ferric oxide appears to be reduced according to the following equations:

$$3Fe_20_3+CO=2Fe_30_4+CO_2$$
$$Fe_30_4+CO=3Fe0+CO_2$$
$$Fe0+CO=Fe+CO_2.$$

The nearly horizontal portion of the CO_2 curve in Fig. 1 corresponds generally to the reduction of Fe0 to Fe, the earlier reactions being effected very readily in the initial part of each reduction. The different stages of reduction can be seen more clearly in the equilibrium curves for the reduction of ferric oxide, determined by Matsubara,[2] Fig. 2, which show the relation between the solid and gaseous phases.

In this curve the first horizontal line indicates the reduction of Fe_20_3 to Fe_30_4; the second horizontal line the reduction of Fe_30_4 to Fe0, and the third the reduction of Fe0 to Fe. During each of these stages there are present two solid phases. The vertical portions of the curve do not correspond at all closely with the compounds Fe_30_4 and Fe0. Thus Fe_30_4 contains 26.17 per cent. of oxygen, while the vertical line is located at about 28 per cent. Also Fe0

[2]A. Matsubara, "Chemical Equilibrium between Iron, Carbon and Oxygen," Trans. Amer. Inst. Min. & Met. Eng., February, 1921.

contains 22.27 per cent. of oxygen, while the corresponding vertical line is located at about 24 per cent. of oxygen. The positions of these vertical lines vary somewhat with the temperature and probably depend on the mutual solubility of the compounds, thus the first vertical line may correspond with Fe_3O_4 with Fe_2O_3 dissolved in it. The final inclined part of the curve, when less than 4 per cent. of oxygen remains, indicates metallic iron with dissolved FeO; all the free FeO having disappeared.

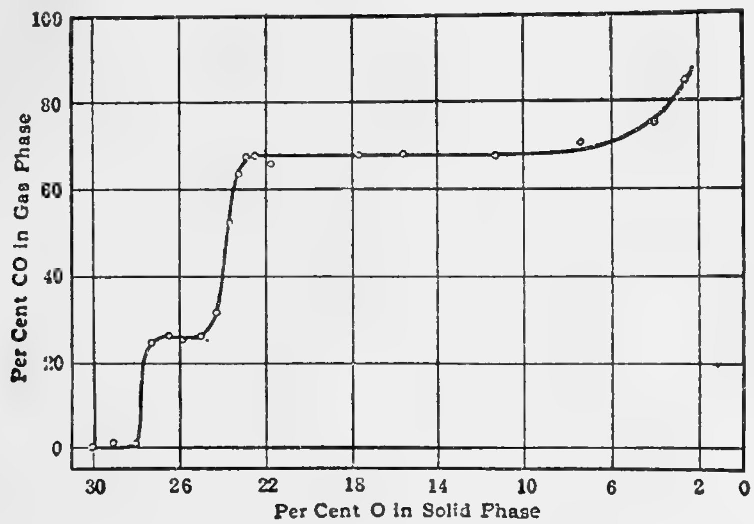


Fig. 2. Equilibrium for the Reduction of Fe_2O_3 by CO at 863°C.—Matsubara.

The present research was directed to finding the rate of reduction rather than the equilibrium conditions, but some approximate measurements of equilibrium, indicated by the dotted line in Fig. 1, were made to show how closely the CO_2 in the issuing gas corresponded with the equilibrium proportion.

The volume of carbon monoxide passed per hour was 1500 c.c. in the earlier experiments, but twice and even four times that speed was employed in some of the later tests.

In Fig. 3 are collected the curves showing the rate of reduction of hematite and magnetite at various temperatures in a stream of 3000 c.c. per hour of carbon monoxide, this stream being sufficiently fast to maintain a decided excess of carbon monoxide throughout the reduction. It will be seen that at 800° hematite is almost perfectly reduced in an hour and a half, while magnetite is only 55 per cent. reduced in that time at 850° and requires three hours for an 80 per cent. reduction at 850° or 900°C. Speaking generally, it appears that hematite ores can be reduced effectively by carbon monoxide at temperatures of 750° or 800°C., while magnetite ores need temperatures of from 850° to 900°C., and even at these temperatures the reduction is far slower.

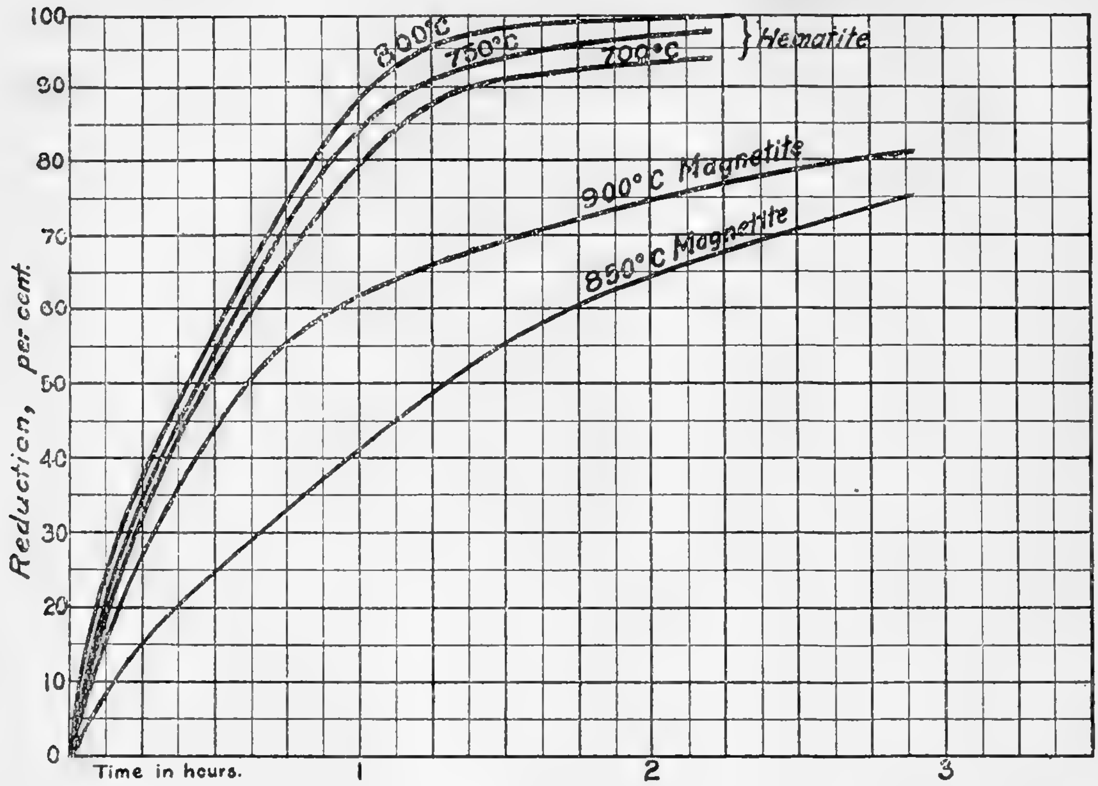


Fig. 3. Rate of Reduction of Hematite and Magnetite at various temperatures.

During the reduction the grains of ore become larger and acquire a characteristic gray colour. Fig. 4 contains photographs, all with the same magnification, showing, on the left, grains of hematite ore in their original condition; in the middle the same ore in the reduced or metallized condition after treatment at 800°C., and on the right a peculiar product obtained on one occasion at 850°C., in which the grains had become coherent and had formed a light spongy mass. It seems curious that the removal of oxygen from an ore should cause an increase of bulk and a careful microscopic investigation of this phenomenon might yield interesting results.

In these experiments the ores were crushed to a uniform size of between 30 and 40 meshes to the linear inch. Earlier work in this laboratory had shown that when the ore was coarser than this the rate of reduction was materially slower, and it was found that the rate was not materially increased when the ore was more finely crushed, apparently because of the poorer contact between the gas and the individual grains of the ore. For magnetite ores, which are slowly reduced in grains of this size, experiments should be made on the effect of finer crushing combined with mechanical agitation of the ore in the gas.

In these experiments the ore was spread as thinly as possible in the boat so as to obtain ample contact with the gas. The contact

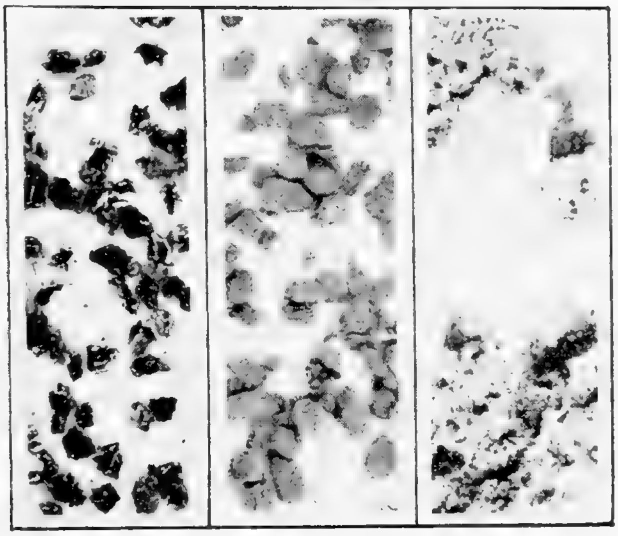


Fig. 4. Hematite Ore before and after Reduction.

between the gas and ore was not perfect, however, and in future experiments this will be improved, perhaps by mechanical agitation. Tests will also be made with "producer gas" instead of carbon monoxide, as the latter could not be used commercially. A series of tests are contemplated that will give comparative results for a number of typical ores.

In earlier experiments in this laboratory by Mr. George Kendall, the rate of reduction of iron ores by charcoal and other solid forms of carbon was studied. The present research into the reduction of these ores by gases should make it possible to compare, quantitatively, the reduction by solid carbon and by gases, and will form a basis of experimental fact on which it should be possible to work out a commercial method for the reduction of iron ores to a metallic powder.

Department of Metallurgy,
McGill University.
May, 1922.

On the Liquefaction of Hydrogen and Helium (II Communication)

By PROFESSOR J. C. MCLENNAN, F.R.S., and G. M. SHRUM, M.A.
University of Toronto

I. *Introduction*

In a previous paper[1] by one of the authors, the details were given of an apparatus that had been designed and adapted in the Physical Laboratory of the University of Toronto for the liquefaction of hydrogen. This piece of apparatus proved to be quite satisfactory for preliminary work, but it has since been replaced by another of a somewhat modified design. The operation of a closed cycle for the liquefaction of hydrogen requires considerable experience and knowledge of technique, and in view of this it seemed advisable during the initial stages to construct the apparatus on a unit system. As the work progressed, however, and the preliminary plans made for the construction of a helium liquefier showed that possibly 30 to 40 litres of liquid hydrogen would be required at one time during the operation of the helium liquefaction cycle, the efficiency of the hydrogen liquefier became a matter of prime importance. It was therefore decided to modify the original apparatus and sacrifice simplicity of construction for efficiency in operation.

A second apparatus was consequently constructed. It has been thoroughly tested and has fulfilled all the exacting demands made upon it. A description of the apparatus and the method of operating it is given in Section IV.

The work on the design and construction of the equipment constituting the cycle for the purification and liquefaction of helium has also been completed, but an unfortunate delay in the delivery of suitable vacuum flasks makes it impossible at present to report a successful operation of this equipment. In Section VII there is given the details of the apparatus and the method we propose to follow in using it.

II. *Compressors and Gasometers*

The hydrogen is compressed by means of a specially designed four-stage belt-driven compressor (see Fig. 1, also Plate I, 1) built by the Burckhardt Engineering Works of Basle, Switzerland. The cylinders are water-cooled, have a forced oil lubrication and are fitted

[1]McLennan, Trans. Roy. Soc. of Canada, May, 1921.

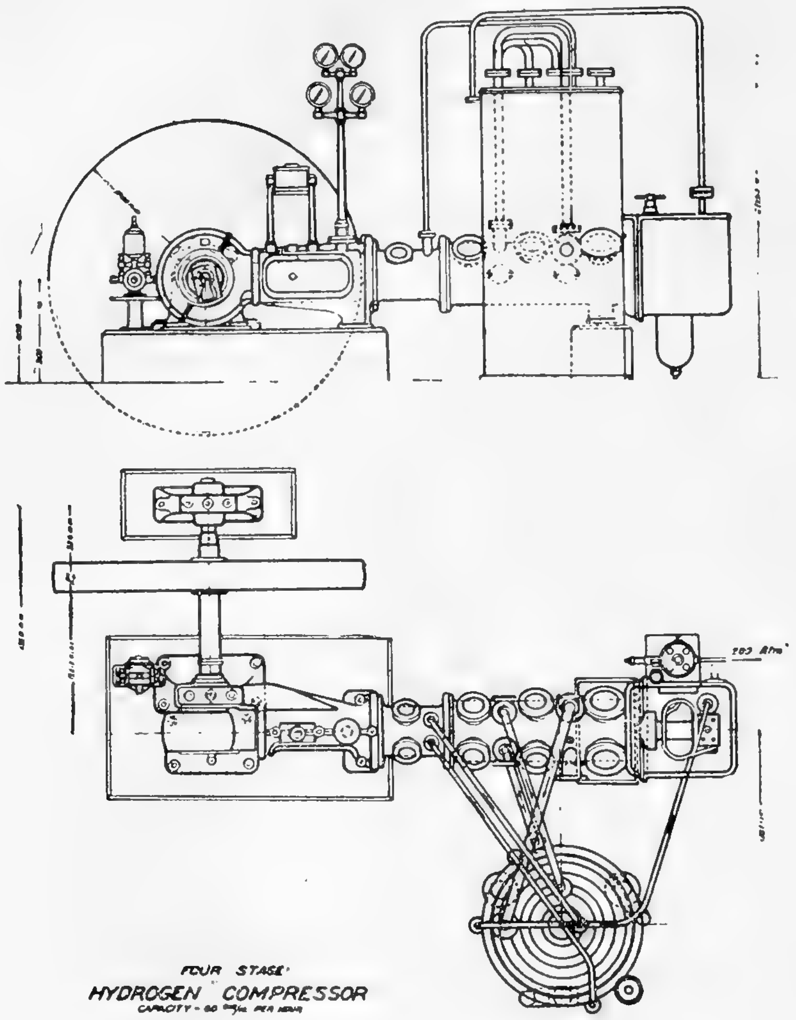
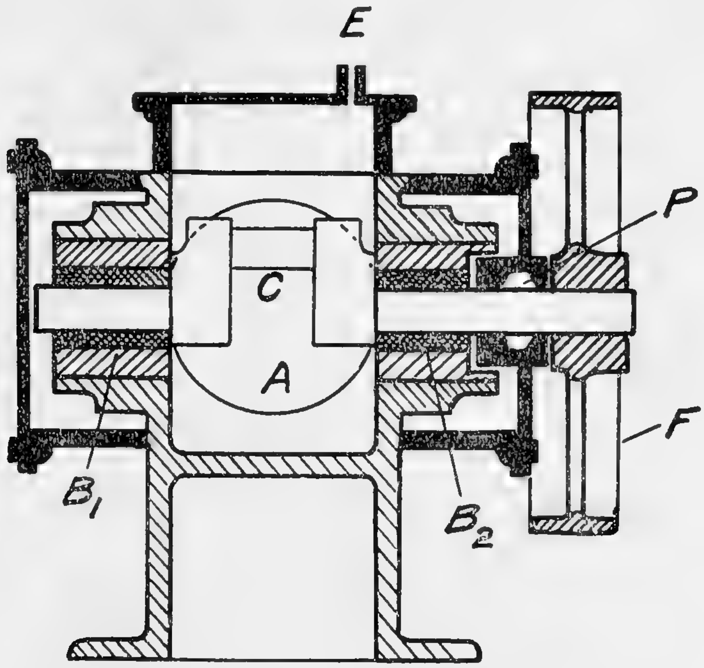


Fig. 1

with steel piston rings. The gas is cooled after each compression by means of a number of inter-coolers immersed in a tank of running water. The compressor is constructed so as to prevent any loss of gas, and with this end in view the piston rods are provided with special stuffing boxes in which the packing is sealed with oil holders. The space back of each piston, as well as the safety valves, are so arranged that they connect with the gasometer, and through the latter to the intake of the compressor. The compressor has a capacity of 60 cubic metre of free gas per hour, and requires a motor of 30 H.P. to operate it when delivering at 200 atmospheres pressure. Twenty litres of water per minute are disposed of by the inter-coolers.

We propose compressing the helium by means of a standard two stage Whitehead air compressor (Plate I, 2) that has been modified for use with rare gases (Plate I, 3). These modifications were made by completely enclosing the crank case with three castings electrically welded to the frame to which plates are bolted (Fig. 2). When the



CROSS-SECTION SHOWING ADDITIONS TO WHITEHEAD COMPRESSOR

Fig. 2

pump is in operation the crank case A is kept partially filled with oil so that as the crank revolves the bearings B_1 and B_2, together with the stuffing box P, are well lubricated. The gas that leaks past the pistons of either the first or second stage is collected in this chamber, from which it is conducted through an oil-trap attached at E, to the low pressure intake.

The maximum capacity of this compressor is 600 cu. ft. of free gas per hour, but a simple and ready means of reducing this by any desired amount has been devised.

For the hydrogen cycle one gasometer of 60 cu. ft. capacity is installed, while for the helium cycle there are two with a capacity of 25 cu. ft. each. These gasometers are made from gauge No. 10 black iron, with welded seams, and an upper frame-work of channel iron. The gas-holders float on oil and are suspended by means of counter weights with roller-bearing pulleys. Since it is inadvisable to use any but a high grade oil the gasometers are arranged with an inner or third cylinder to reduce the amount of oil required. Glass check valves are arranged through which the oil of the gas-holder can be visibly drawn up and automatically checked. This latter arrangement eliminates the danger of crushing in the gas-holder or of pumping oil over into the piping system, should the pressure in the latter become much less than atmospheric. The gasometers are joined to the piping system by means of wire-lined flexible gasoline hose.

III. *The Hydrogen Cycle*

Plate 1 of the previous communication[2] plainly shewed the general arrangement of the hydrogen cycle. The installation represented in the above plate has undergone none but minor alterations, except for the gasometer that has been added to the low pressure system already described in Section II of this paper.

Ordinarily the gas is kept under pressure in steel cylinders tested to 200 atmospheres pressure. From the cylinders it is introduced by means of reducing valves into the gasometer from which it passes to the intake of the compressor. After compression the gas is passed through oil and water separators and then to the purifying or liquefying cycles, from whence it returns again at low pressure to the intake of the compressor. Extreme precautions are taken to prevent the escape or loss of gas in any manner. To this end all valves and unions are immersed wherever possible in heavy oil, that serves to indicate instantaneously a leak and prevents air from contaminating the system during the exhausting of the apparatus. By these means it is possible to run the cycle continuously without introducing more gas into the system than is required to replace that which is condensed as liquid. After each operation the gas is collected and compressed into the steel cylinders where it is safely stored until required.

IV. *The Purification of the Hydrogen*

The commercial hydrogen that we are using may contain, we find, when manufactured electrolytically, as much as 1.5 per cent. oxygen and from 0.1 per cent. to 0.3 per cent. nitrogen. The presence of oxygen may be accounted for by the diffusion that takes place in the porous plates of the electrolytic cell, but the presence of nitrogen is due probably to contamination during the compression or storage.

In our operations the preliminary purification of the commercial hydrogen is effected by passing it through a high pressure bomb filled with palladiumized asbestos. This bomb is heated electrically to about 350°C. at which temperature the palladium acts as a strong catalyst, and the oxygen and the hydrogen combining to form water is later condensed in a trap or taken up by caustic potash. When the hydrogen at a pressure of 200 atmospheres is passed over this asbestos a number of times the content of oxygen in the hydrogen may be reduced to less than 0.1 per cent.

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[2]McLennan, Trans. Roy. Soc. of Canada, May, 1921.

Shakspear katharometers have been found to be almost indispensable for testing the hydrogen during the operation of the cycle, and while using them they are frequently calibrated and checked by means of hydrogen that has been chemically analysed, or tested by other physical means.

It is well known, however, that any trace of impurity in the hydrogen—other than helium—will be condensed and later solidified in the expansion coil of the hydrogen liquefier. Such condensation and solidification finally results in a complete stoppage of the expansion valve or of the tubes of the expansion coil. It is only possible, therefore, with other than absolutely pure hydrogen to make a limited amount of liquid hydrogen during each operation. In order to make 30 or 40 litres of liquid hydrogen without failure it is necessary to have available a large supply of extremely pure hydrogen. This is accomplished by an arrangement similar to that employed by Professor Kammerlingh Onnes in the Cryogenic Laboratory at Leiden.[3] It consists of an apparatus in which the gaseous impurities in impure hydrogen are condensed out by means of liquid hydrogen. Fig. 3 represents the apparatus schematically.

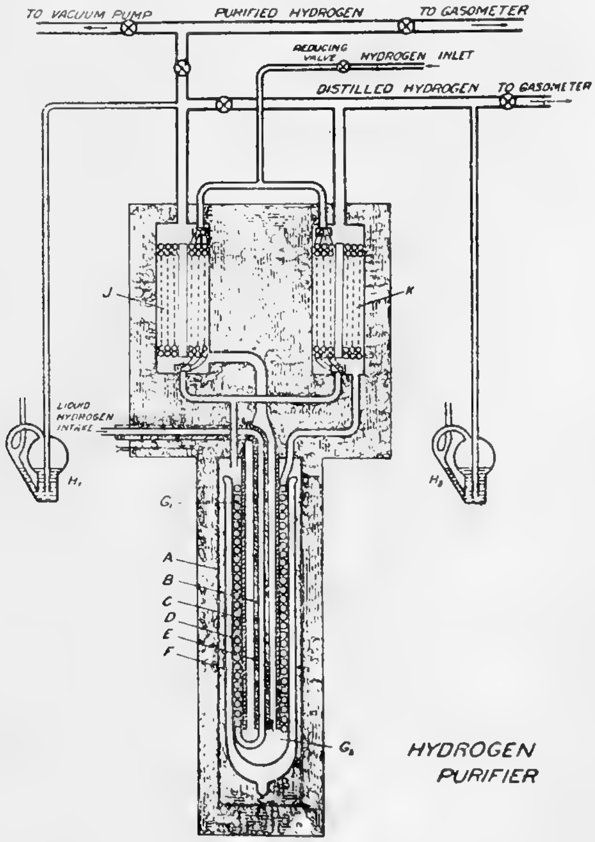


Fig. 3

[3]Kon. Akad. Weten, Amsterdam, 11, 1908-09.

Liquid hydrogen is siphoned into the apparatus through the insulated tube E to the lower end of the large spiral D. The hydrogen that is to be purified is controlled by a reducing valve, and enters the coils of the two exchangers J and K arranged in parallel. It then passes down over the outside of the spiral D. As the liquid hydrogen is continuously vapourized within this spiral the latter is kept at a very low temperature with the result that the gaseous impurities are condensed out upon the external surface.

The vapourized hydrogen rises in the spiral and passes out through the regenerator K to the gasometer. The purified hydrogen, upon reaching the bottom of the spiral, passes upward through a fibre tube and the regenerator J to the gasometer, from which it is compressed into cylinders.

A silvered vacuum flask F insulates the coil while a German silver cylinder A supports the flask and serves to keep the apparatus hermetically sealed. Thermocouples G_1 and G_2 serve to determine the rate of flow of the gas, since they indicate the temperature along the spiral. The arrangement of the connecting pipes is shown clearly in Fig. 3 in which H_1 and H_2 are mercury safety valves that protect the apparatus at all times. The purifier is entirely wrapped in wool and surrounded with a brass case as shown in Plate II, 1.

It is capable of purifying approximately 5 cubic metres per hour and requires in this time about 5 litres of liquid hydrogen. It is not suitable for work with hydrogen that has not undergone a preliminary purification, as during the operation all the impurity in the gas remains behind as solid, and is only removed at the close of the operation, when as the temperature rises the nitrogen or other impurities are drawn off by means of a vacuum pump.

V. *The Hydrogen Liquefier*

The liquefier is represented schematically by Fig. 4, while Plate II, 2 shows a photograph of the apparatus as it is installed in the Physical Laboratory at Toronto. It will be recognized that the principle of the construction is the same as that of the apparatus described in the first Communication from the Laboratory on this subject. The Joule-Thomson effect and Dewar's ingenious method of placing the regenerator coil in a vacuum flask are utilised. The regenerator coils are similar to those used in Hampson's apparatus for liquefying air. A number of features peculiar to the Leiden installation are also included.

Pure hydrogen is compressed to 200 atmospheres and cooled to $-205°$C. by means of liquid air boiling under reduced pressure.

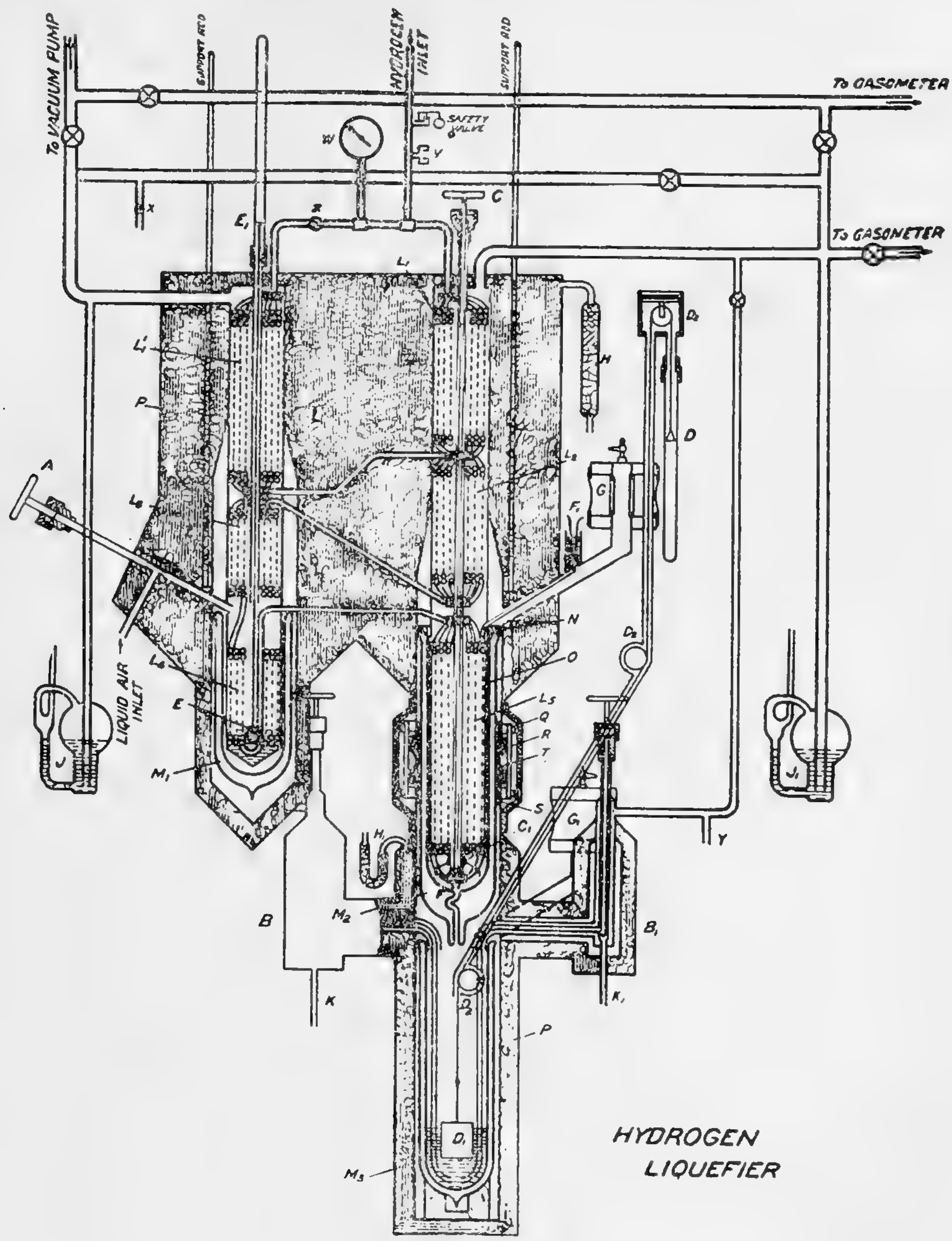


Fig. 4

The gas is then expanded from a nozzle and as a result of the regenerative cooling the temperature falls below the boiling point and liquid hydrogen is separated out.

The compressed hydrogen passess successively through the coils L_1, L_1', L_2, L_3, L_4, and L_5, Fig. 4. L_1 and L_1' are arranged in parallel and the valve Z serves to regulate the proportion of gas going through each of them. This insures the proper interchange of heat between the oncoming compressed gas and the out going low pressure vapours.

The coils L_1, L_2 and L_5 are cooled by gaseous hydrogen returning to the gasometer from the expansion cock C_1. L_1' and L_3 are cooled by evaporated air being drawn off by the vacuum pump, and L_4 is partially immersed in a bath of liquid air contained in the flask *M*. The valve *A* serves to admit more liquid air from the reserve flasks whenever the indicator E_1 of the cork float *E* shows that it is required. The expansion or chief regenerator coil is well wrapped in flannel and still further protected by the double walled silvered vacuum flask M_2. The liquid, as it is formed, passes through the opening in the bottom of the flask M_2 and is collected in the silvered flask M_3. The float indicator D, D_1, D_2 serves to show the level of the liquid in this collecting flask. The weight *D* is connected with the thin German silver float D_1 by means of a silk thread running over three pulleys D_2 each with jewel mountings. Two valves, *B* and B_1, are used for drawing off the liquid. These valves are so arranged that they may be pre-cooled by the cold gaseous hydrogen that may be returned to the gasometer. The stuffing boxes and screw thread for the valves *B*, B_1, *C* and *A* are so arranged that they are not exposed to cooling and thus the danger of freezing is eliminated.

The insulation of the apparatus has been carefully studied. Vacuum flasks are used where possible and wherever parts are cooled below the temperature of liquid air, they are surrounded by an atmosphere of hydrogen or by a partial vacuum, in order to avoid unnecessary condensation. The regenerator coils are wrapped in flannel and fit snugly in German silver containers so as to insure a proper exchange of heat between the incoming and outgoing gases. All parts as far as possible are constructed of German silver, because of its low coefficient of thermal conductivity. The entire apparatus is packed in natural wool and enclosed in a thin brass case that is sealed except for the drying tubes *H* and H_1. These tubes serve to prevent water vapour from condensing and collecting inside. Fig. 4 shows plainly the arrangement for supporting the apparatus, together with the scheme of the pipe connections. Mercury traps *J* and J_1 serve to protect the apparatus at all times from any excess of pressure, while rubber safety valves *G* and G_1 serve to accommodate any sudden or violent increase in pressure.

When it is required to operate the cycle the complete system of piping, etc., is thoroughly exhausted. It is then filled with hydrogen and again exhausted, the operation being repeated until the hydrogen in the system is absolutely pure. The refrigerator surrounding the coil L_4 is then filled with liquid air and the pre-cooling is effected by allowing the hydrogen to stream through at low pressure for some time. When the thermocouples indicate that the temperature of the hydrogen at the expansion valve is $-205°$C., the valve is gradually closed until the pressure reaches 200 atmospheres. Some of the cold hydrogen is used to pre-cool the valves B and B_1 and various other parts of the apparatus. As liquid is drawn off it is necessary to introduce fresh hydrogen into the gasometer. The liquefier will deliver 10 to 15 litres of liquid hydrogen per hour. The pre-cooling of the coils requires about 10 litres of liquid air per hour. Thus a very moderate supply of liquid air is quite sufficient for the production of a large quantity of liquid hydrogen.

VI. *The Helium and its Purification*

The helium was obtained by Professor McLennan from the natural gas of the Bow Island district, near Calgary, Alberta, in the year 1919-20, and has been kept since then safely stored in steel cylinders at about 150 atmospheres pressure. An analysis by means of absorption with cocoanut charcoal showed that it was about 90 per cent. pure. The impurity consisted chiefly of nitrogen with a varying percentage of methane. A Shakspear katharometer, such as is ordinarily used for hydrogen has been properly calibrated and is mounted for testing the purity of the gas during the operation of the cycle.

It is proposed to eliminate a large percentage of the impurity in the helium by means of the condensation produced as it is cooled by liquid air boiling under reduced pressure. In this manner, when the pressure of the helium is 150 atmospheres, the percentage of nitrogen may be reduced to less than 0.5 per cent. The remainder of the impurity other than hydrogen it is proposed to absorb by means of cocoanut charcoal at the temperature of liquid air. Traces of hydrogen are removed by absorption with Cu O, or burning with oxygen in the presence of palladiumized asbestos.

Fig. 5 shows the apparatus diagrammatically while Plate II, 3 is a photograph of the actual installation. The impure gas enters the outer tube of a spiral generator of the Linde type and passes thence through a spiral coil immersed in liquid air boiling at a pressure of 5 cms. of mercury. Any impurity that is condensed collects in the trap T while the purified gas passes through the central tube of the spiral regenerator to the valve V_1. The impurity from the trap is drawn off and collected through the micrometer valve V_3. An analysis of the gas that is collected serves to determine the quantity that should be drawn off. The level of the liquid air is shown by the indicator B of the cork float B_1. The valve M controls the supply of liquid air that is drawn over into the apparatus from the store bottles. Insulation for the apparatus is provided by a silvered vacuum flask F

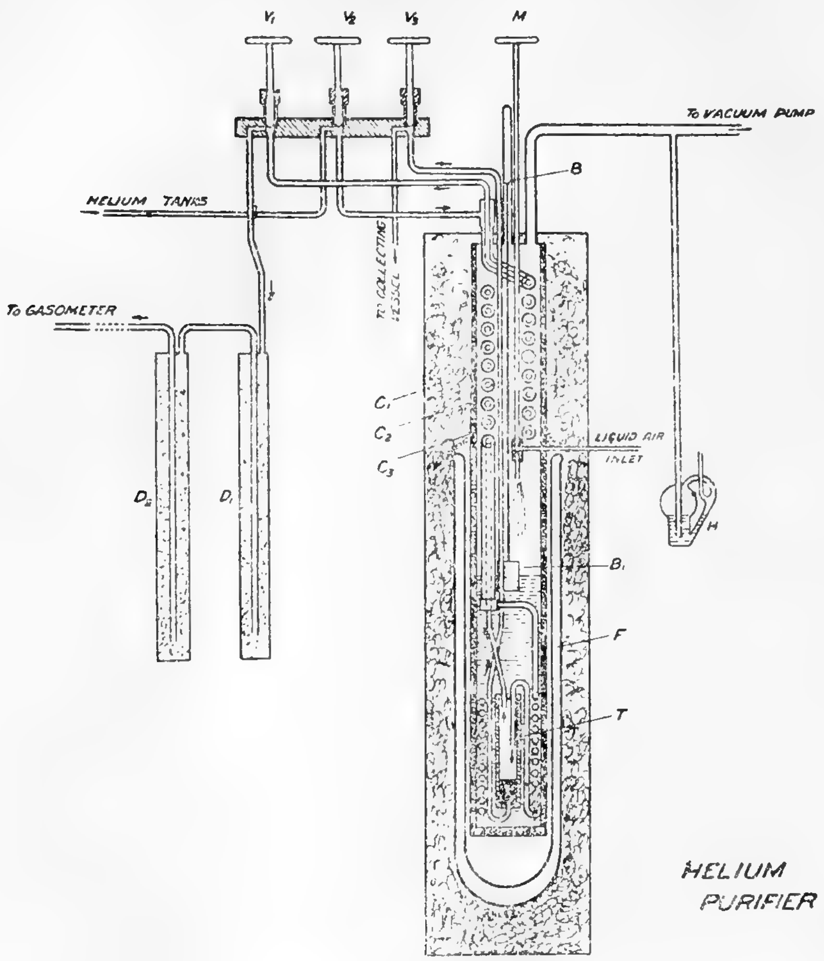


Fig 5

and a swathing of natural wool. After being partially purified in the manner indicated the gas is passed through the reducing valve V_1, and at low pressure through six cocoanut charcoal tubes, D_1, D_2, etc. From these it is collected in the gasometer and finally compressed into tanks, to be introduced later into the liquefying system. In the construction of the apparatus care was taken to reduce its size to a minimum, so that the consumption of liquid air would not be very great, even although the alternate heating and cooling of the charcoal tubes necessitated our making the process of purification a discontinuous one.

VII. *The Helium Liquefier*

As the design of the hydrogen liquefier proved to be a highly efficient one it was deemed advisable to construct the helium liquefier on the same general principles, but on a considerably reduced scale. It will be recalled that in the operation of a helium liquefier, liquid hydrogen must be employed to cool the helium below the temperature at which the Joule-Thomson effect changes sign. When the gas is

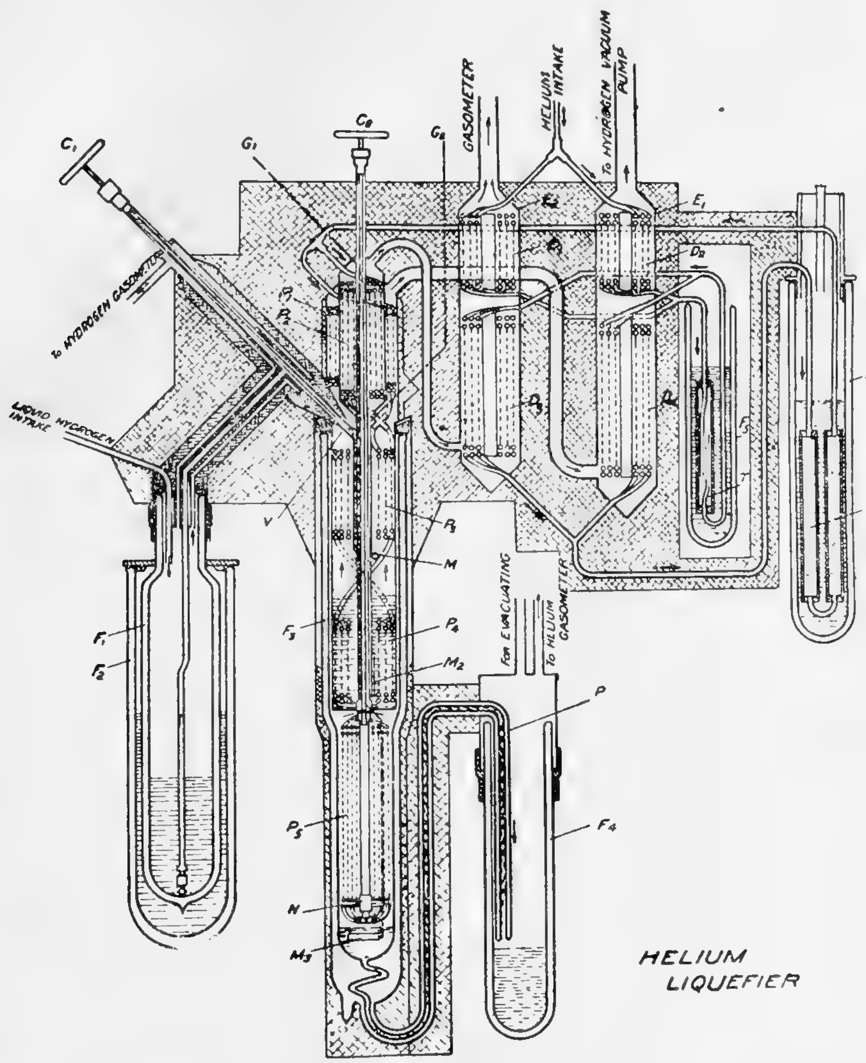


Fig. 6

reduced to this temperature it must then be expanded from a nozzle with the application of the principle of regenerative cooling. In the design of our helium liquefier provision was made for these features. The arrangement of parts is shown in Fig. 6.

The gas enters at the intake indicated in the figure. It passes successively through the coils D_1, D_2 and D_3, D_4 arranged in parallel. It then enters P_1 and P_2 also in parallel and afterwards passes successively through P_3, P_4, P_5. D_2, D_4, P_1 and P_3 are to be cooled by the vapourized hydrogen that is drawn off by the hydrogen vacuum pump. D_1, D_3, P_2 and P_3 serve as exchangers for the expanded helium. The coil D_4 is to be partially immersed in liquid hydrogen boiling at a pressure of 5 cms. of mercury. The trap T is to be kept immersed in liquid air in order that the last traces of oil or water vapour coming from the pump may be condensed out. B_1 and B_2 are bombs to be filled with charcoal and kept at the temperature of liquid air so that any gaseous contamination introduced into the helium in the working of the cycle may be removed. Provision is being made for indicating the level of the liquid hydrogen in the refrigerator by means of two constant volume helium thermometers with bulbs M and M_2. These bulbs are made of German silver and are to be connected to glass manometers by means of steel capillary tubing. The valve V, with its spindle C_1 both pre-cooled with gaseous hydrogen, will enable one to regulate the supply of liquid hydrogen. The flask E that is to be used for storing a reserve supply of liquid hydrogen is not to be silvered and is to be kept immersed in a flask F_2 filled with liquid air. This latter flask is to be provided with two unsilvered observation strips on either side to enable one to see the level of the liquid hydrogen directly. Provision is also made in the design for siphoning liquid hydrogen from the store bottles into the reserve flask F_1 and since the vapourized hydrogen will necessarily be almost absolutely pure, provision has been made in the apparatus for carefully collecting and storing it.

The helium, as it is condensed on liquefaction, will collect in the bottom of the silvered flask F_3 that is to be made with a specially designed delivery tube P. This tube will be double walled and silvered in the same manner as an ordinary vacuum flask. In this way it will be possible to transfer the liquid helium to the flask F_4 or to any other suitable apparatus in which it may be required. In the design of the apparatus every precaution has been taken to prevent loss of helium or its contamination with hydrogen.

8. *Summary*

In the statement above there are set forth the underlying principles, the design and many details as well of the equipment that will soon be completely installed in the Physical Laboratory of the University of Toronto for the purpose of liquefying hydrogen and helium.

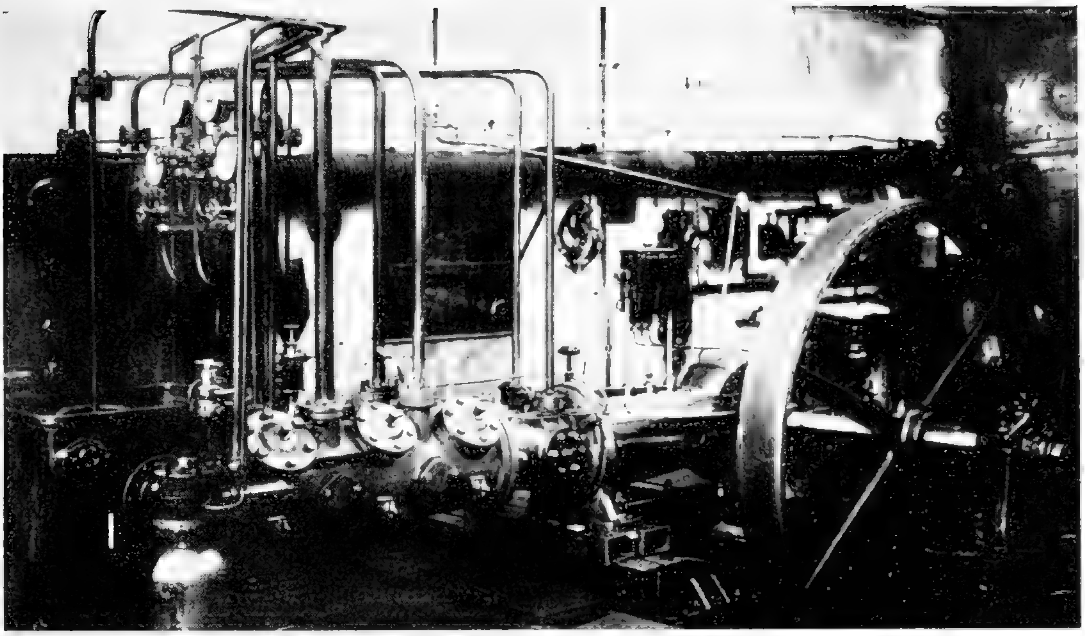
Note.—While presenting this paper I desire to take the opportunity of acknowledging my very great indebtedness to Professor Kammerlingh Onnes of the University of Leiden, Holland.

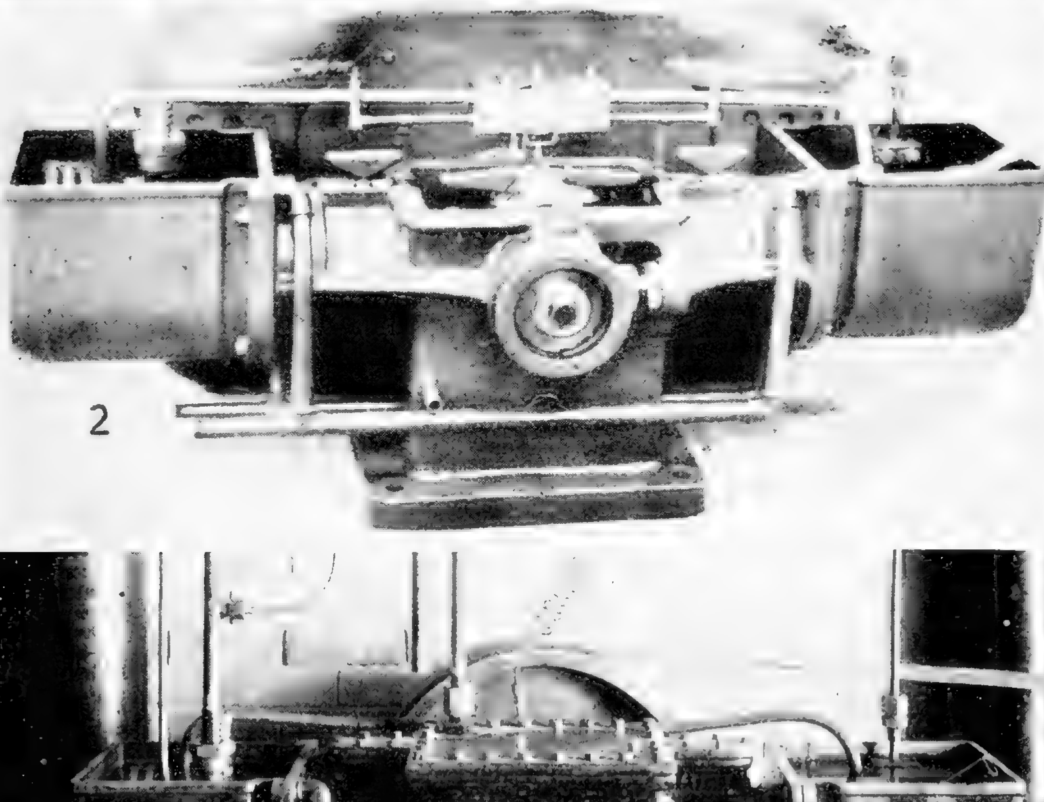
The hydrogen purifier and liquefier, as well as the helium liquefier, were designed in accordance with drawings furnished to me by him. I also had the benefit of his advice in working out the details of the hydrogen compressor.

Through conversation and correspondence I gained much information from him that enabled me to expedite the construction and installation of our cryogenic equipment. To him I offer my sincere thanks.

J. C. McLennan.

Physical Laboratory,
University of Toronto.
June 15, 1922.





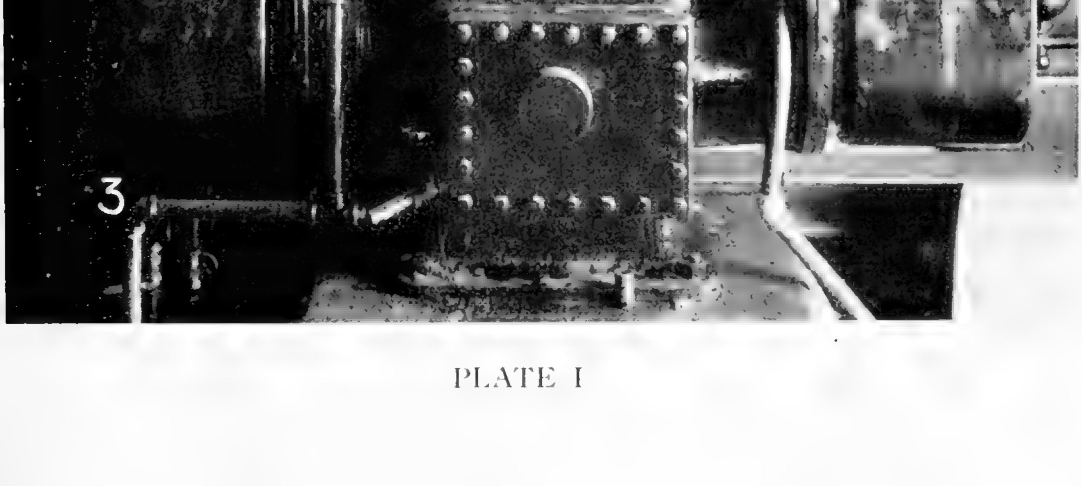


PLATE I

On Infra-Red Spectroscopy

By MR. V. P. LUBOVICH and MISS E. M. PEAREN, B.A.
University of Toronto,
with
Introductory note by PROFESSOR J. C. MCLENNAN, F.R.S.

(Read May Meeting, 1922)

INTRODUCTORY NOTE

For many reasons it has become desirable to extend as far as possible into the infra red region of spectra the use of various optical methods that have been found to be applicable to the investigation of the properties of radiations in the visible and ultraviolet portions of spectra.

To make the use of a number of these methods practicable it is necessary to adopt the photographic method of recording spectra. From the fine work of Meggers, Kiess, Merrill and Walters, and from some limited work that has been carried out by the writer, it is now clear that spectra can be photographed as far in the infra-red as λ 11,000 A. The conditions under which such work can be done best are not, however, as clear as they might be, and with a view to extending our knowledge in this regard, a series of investigations on infra-red spectra and on photographic and other methods of recording them, was recently carried out in the Physical Laboratory of the University of Toronto. This work has been made possible through a grant from the Honorary Advisory Council for Scientific and Industrial Research of Canada, with which I was enabled to obtain the services of Mr. V. P. Lubovich.

In the following communication an account is given of some of the results obtained which are likely to be of general interest. The paper is divided into two parts, the one containing results obtained for me by Mr. Lubovich, and the other results obtained by Miss Pearen, who was able to devote only a limited portion of her time to the investigation of some aspects of the problems before us.

J. C. MCLENNAN

DIVISION I

By Mr. V. P. Lubovich

Part I. Infra Absorption of Aniline Dyes and Coloured Glasses

(1) *Introduction.*

Recent work by Meggers,[1] by Meggers and Kiess,[2] and by McLennan and Shaver[3] shows that the photography of the spectrum can be extended into the infra-red by using plates stained by certain selected dyes. From the investigations cited above it is clear that to get measurable results up to λ 9000A exposures of from 20 to 30 minutes are quite sufficient, but beyond this limit it is possible to photograph only with exposures ranging from 5 to 32 hours.

According to investigations by Vogel[4] and Eder[5] the maximum of sensitivity of stained plates is always about 30 A on the red side of the absorption maximum of the dye used. With this in mind a research was undertaken on the absorption of the different dyes used by the authors mentioned above, with the object of finding out which dye could be used most successfully, for photography beyond λ 9000A. Owing to the small dispersion of prism spectrographs in the infra-red, and also to the absence of well mapped standards accurate measurements of photographed lines are possible only with grating spectrographs. This fact makes it necessary to cut off high order spectra by using filters. As experience has shown that it is not always possible to rely on the data given by manufacturers of filters the opportunity has been taken of coupling the investigation of the dyes with the study of different filters, in the hope that the results might prove useful in infra-red photography.

(2) *Method*

Owing to the fact that all staining baths contain a considerable amount of ethyl alcohol and a very low percentage of dye, alcoholic solutions of 1/10000 in four cases, and of 1/2000 in one case, were investigated. As alcohol itself absorbs infra-red radiation in the

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[1]Meggers, Bull. of the Bureau of Standards, Vol. 14, 1917.

[2]Meggers and Kiess, Bull. of the Bureau of Standards, No. 324.

[3]McLennan and Shaver, Proc. Roy. Soc., A. Vol. 100 p. 200, 1921.

[4]Vogel, Berichte, No. 6, p. 1302, 1873, No. 7, p. 976, 1874.

[5]Eder, Wien Berichte, 90 I, p. 1097 (1884), 92 II, p. 1346, 1885, 93 II, p. 4 (1886), 94 II, p. 75 and p. 378, 1886.

region to be investigated, a differential method was adopted, involving the use of a thermopile and galvanometer.

The deflection d_1 was taken when the radiation was passed through a given thickness of alcohol and an instant later the deflection d_2 was taken when the radiation was passed through an equal thickness of dye solution. In this way the difference d_1-d_2 was obtained. The deflection d, when the radiation was passed directly into the spectrometer without any absorption cell was then observed. The readings for d_1, d_2 and d were taken at each 0.1μ of the spectral region investigated at least five times, or until consistent results were obtained. The percentage relative absorption was calculated from the equation

$$\text{Absorption} = \frac{d_1 - d_2}{d} \times 100.$$

As to the investigation of filters it has been pointed out that the study was proposed from the point of view of the need of infra-red spectroscopy, which involves two questions:

1. How great is the transmission of a filter in the red and infra-red?

2. Is there a narrow region of transmission for short wavelengths which might be a source of error when the filter is used with a grating?

As far as transmission is concerned, a method of study was used similar to that adopted in the study of the relative absorption of the dyes, with the difference that the deflection d_1 was taken when the radiation passed through a given filter, d_2 when the radiation passed through a given filter plus a plate of glass 3.5 mm. thick, and d when the radiation passed into the instrument without any filter in its path. The per cent. relative transmission was calculated from the equations.

$$\text{Transmissions of a filter} = \frac{d_1}{d} \times 100$$

$$\text{Transmission of a filter plus glass} \frac{d_2}{d} \times 100.$$

Different Wratten light filters were studied, and the solution of problem (2) obtained in the following way:

The spectrum of mercury was photographed four times on one plate—

(*a*) Without any filter.

(*b*) Through the first filter of the proposed combination.

(*c*) Through the second filter, which was intended to cut off some undesirable lines.

(*d*) Through the combination.

A quartz prism spectrograph and Wratten panchromatic plates were used. Exposures ranged from 2 min., when no filter was used to 2 hours in the case of dense filters, in order to make certain that no radiation of short wave-length could pass without being noticed.

(3) *Apparatus*

The apparatus used is shown in Fig. 1. It is fully described by McLennan and Dearle.[6] The radiation from a 400 watt nitrogen

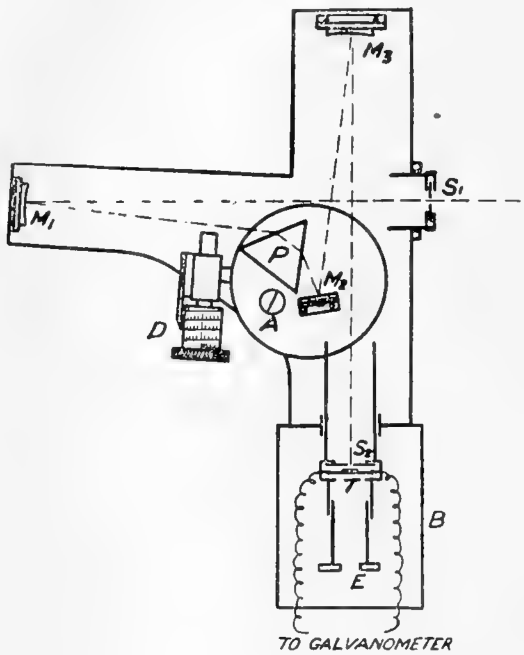

Fig. 1

filled lamp was focussed on the slit s_1 by means of a glass lens of 28 cms. focal length and 10 cm. diameter. From this slit the rays passed to the nickel steel concave mirror m_1, thence through the rock-salt prism p to the plane nickel mirror m_2. From this they were reflected to the concave nickel steel mirror m_3, and by it they were brought to a focus on the linear junctions of the thermopile at t, which was placed immediately behind the slit s_2. The prisms and plane mirror were mounted on a table which rotated about a point a. By turning this table through a small angle any desired part of the spectrum could be brought to a focus at s. The rotation was produced by the motion of a helical drum attached at d, which was calibrated in wave-lengths up to 10μ. An eyepiece e could be attached behind the slit s_2 for the purpose of focussing lines in the visible part of the spectrum, on the thermopile, and of adjusting the prism so that the radiation brought to a focus at s_2 was in agreement with the reading on the drum.

[6]McLennan and Dearle, Phil. Mag. 30, p. 683, 1915.

The thermopile consisted of 10 junctions of bismuth silver, joined by silver solder, and flattened out into rectangular plates at the exposed junctions, which were blackened. The galvanometer used was of the Paschen type.[7] The sensitivity of the instrument was such that a deflection of 1 mm. on a scale at the distance of one metre was produced by a current of 5×10^{-10} amperes.

To avoid the variation produced by temperature changes, and by stray air currents, the thermopile and slit were enclosed in a nickel-plated metallic box shown at *b*.

The whole spectrometer was enclosed in a wooden box lined with absorbent cotton. The box had a window at s_1 covered by a shutter, and a second window through which to read the wave-lengths on the drum.

During the experiment the slits s_1 and s_2 were 0.3 mm. wide.

The lamp was supplied with direct current from the mains.

To avoid errors due to the variation of voltage the lamp was connected in series with a rheostat by means of which a constant difference of potential, 115 volts, was kept at the binding posts of the lamp.

The cells which contained the solutions were made of glass 2.5 mm. thick, and had 5 mm. distance between the walls.

Preliminary measurements of absorption of alcohol, through both cells gave results coinciding within one per cent. During the experiment the cells were always placed at the same point in front of the slit s_1.

(4) *Results*

The absorption for alcoholic solutions of concentration 1:10000 of Dicyanin, Dicyanin A, Pinacyanol, Nigrosin SS Blue shade, and of 1:2000 of Alizarin Blue S was observed as described above. The results of these investigations are shown graphically in Fig. 2-6. Fig. 2 shows the absorption curve for Dicyanin. It shows that Dicyanin has a strong absorption up to 0.8 μ. At 0.9 μ it reaches a minimum, and then has nearly constant magnitude up to 2 μ except for a small maximum at 1.0 μ.

Fig. 3 shows absorption for Dicyanin A. It follows from the absorption curve that Dicyanin A has its maximum shifted to the red side of the spectrum, and has a broader region of high absorption, though in magnitude it does not reach 36 per cent., which is the absorption of Dicyanin. These two facts coincide perfectly with

[7]Paschen, Zeit. für Instr. 13, 1. p. 13-17, 1893.

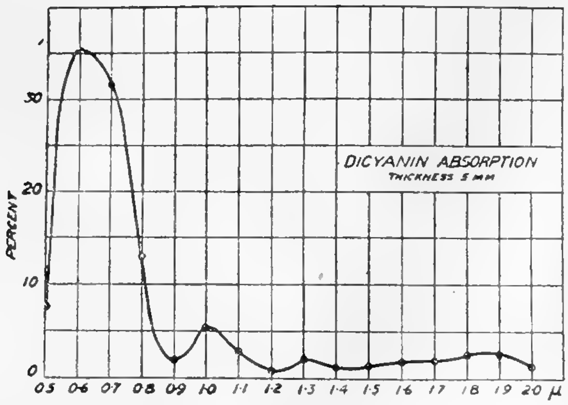

FIG. 2

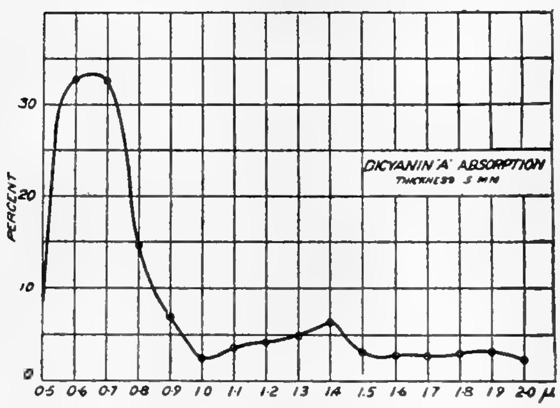

FIG. 3

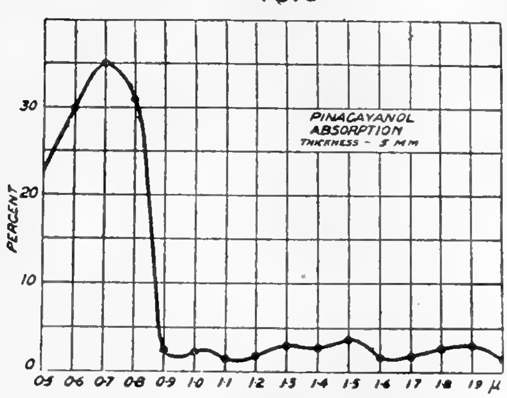

FIG. 4

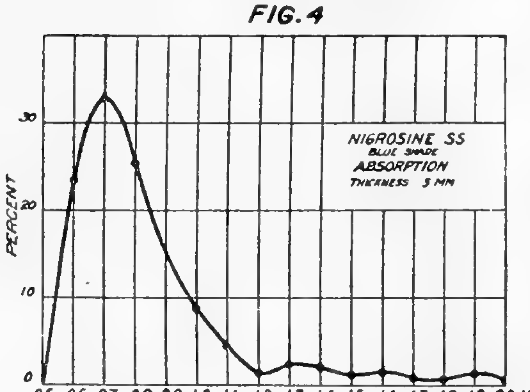

FIG. 5

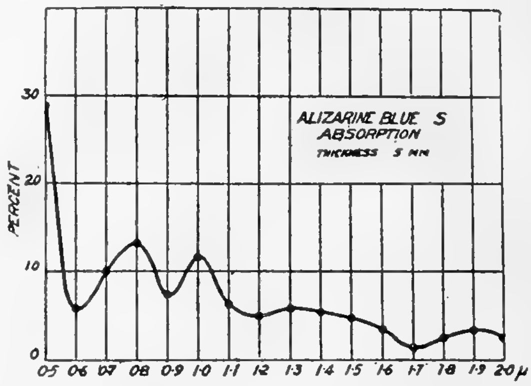

FIG. 6

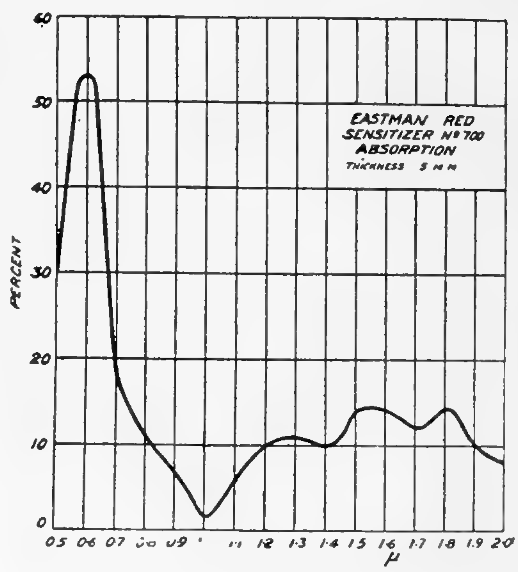

FIG. 7

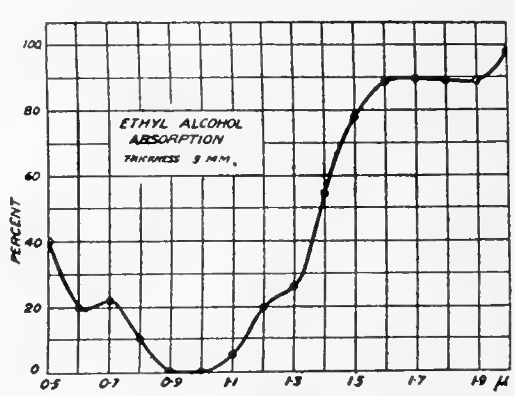

FIG. 8

experimentally known properties of the two dyes, (1) that Dicyanin A is better than Dicyanin for longer wave-lengths and (2) that it must be taken for a staining bath in a little greater concentration.

According to its absorption curve Dicyanin A is better for work at 0.9 μ than Dicyanin, but the latter is preferable for 1 μ although Dicyanin A again has an advantage in account of its greater absorption.

Fig. 4 shows the absorption for Pinacyanol. This dye has a much greater percentage absorption at 0.5 μ than the dyes previously mentioned. At the same time our results indicate that it would work as well as both Dicyanins up to 0.9 μ. The first of these facts is well known, but the second needs experimental verification.

Fig. 5 represents the absorption curve for Nigrosin SS Blue shade. This dye, according to its absorption, should give better results for work between 1.0 μ and 1.1 μ than Dicyanin.

Fig. 6 shows the absorption for Alizarin Blue S. This dye has no maximum at 0.6 μ-0.7 μ, in which it differs from all the dyes mentioned above. Possibly it can be useful at 1.0 μ, thanks to its well marked maximum in this region.

Fig. 7 shows the percentage absorption of a dye recently brought out by Dr. Mees of the Eastman Kodak Co., and known as red sensitiser No. 700. As the diagram indicates there was a relatively strong but narrow band at 0.6 μ. In the region between 1.2 μ and 1.9 μ the relative absorption was exceptionally high. If one can take absorption as an indication of photographic sensitivity this dye should prove very useful in infra-red work up to 2 μ.

Fig. 8 represents the absorption for a 5 mm. thick layer of ethyl alcohol.

The study of the filters is represented in Figs. 9-14, which show the relative per cent. transmission of the following filters: Wratten No. 22, No. 29+No. 22, No. 70+No. 22, No. 36+No. 22, No. 29+No. 45 (Paschen's filter), and 0.1075 mm. thick layer of asphaltum varnish, deposited on a glass 1.1 mm. thick.

Each of the first four filters was studied twice. Curves A represent the transmission of the filter in question and Curve B the transmission of the given filter plus a plate of glass 3.5 mm. thick, which was added to absorb the radiations of very short wave-lengths in case the filter was transparent to them.

Fig. 9 shows that filter No. 22 has exceptionally high transparency for near infra-red radiation ranging from 86 to 89 per cent. Other filters have 70 per cent. as an average transmission.

Figs. 15-19 represent the photographs made with the first five filters in the way explained above. An attempt was made to make corresponding photographs with the asphaltum filter but no noticeable result was obtained. Fig. 15 shows that filter No. 22 begins to transmit in the neighbourhood of λ 4900A and consequently can be used with gratings for work between λ 4900A and λ 9,800A. Fig. 16 shows that filters No. 29 and No. 22 combined are good for work between λ 6,100A and λ 12,200A. Fig. 17 shows that the combination of No. 70 and No. 22 can be used for the region from λ 6,400A up to λ 12,800A. Fig. 18 shows that filters No. 36 and No. 29 begin to transmit at λ 6,700A and consequently can be used for work between λ 6700A and λ 13,400A. Fig. 19, filters No. 29 and No. 45 (Paschen), shows that this filter transmits from λ 6,900A, and can be used for work from λ 7000A and up to λ 14,000A, although it is transparent for a narrow region between λ 3342A and λ 3655A.

Fig. 14 shows asphaltum can furnish a cheap and highly transparent filter for infra-red work.

(5) *Summary of Results*

1. Six different dyes were studied and it was found that they all absorb only to a very small extent rediations of wave-lengths longer than λ 9000A, which fact accounts for the long exposure required for successful photography in this spectral region.

2. The results obtained indicate that the use of proper mixtures of the dyes may prove helpful in photographing beyond λ 9000A.

3. Observations on absorption indicate that, although not so popular, Nigrosin and Alizarin Blue may be of greater use for certain regions of the spectrum than Dicaynin or Dicyanin A.

4. According to the absorption curves photography, as far up as λ 20000A ,should not be more difficult than to λ 10000A.

5. Six useful filters were investigated in two ways, i.e., as to transparency, and as to the region in which they can be most efficiently used.

Part II. On Infra-Red Photography

In a paper published by McLennan and Shaver,[1] it was shown that the mercury spectrum can be photographed as far as λ 11,137A. Photographs of the type produced in their paper were made by means of a grating spectrograph, and required exposures ranging from 17 to 32 hours. Wishing to investigate the influence of different exposures on the stained plates and on the other hand, desiring to

[1]McLennan and Shaver, Proc. Roy. Soc. A, 100, p. 200, 1921.

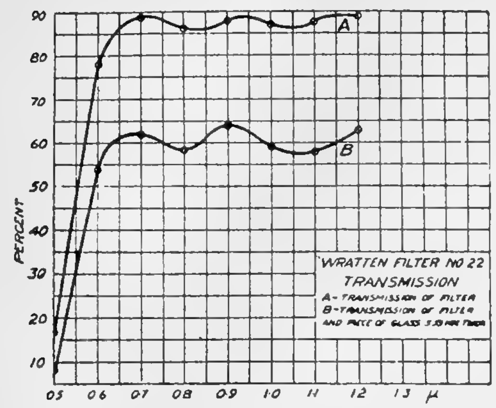

FIG. 9

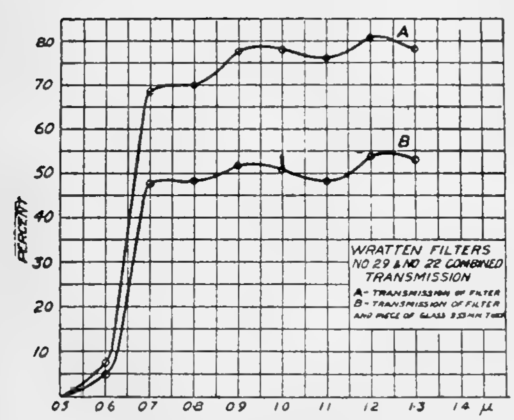

FIG. 10

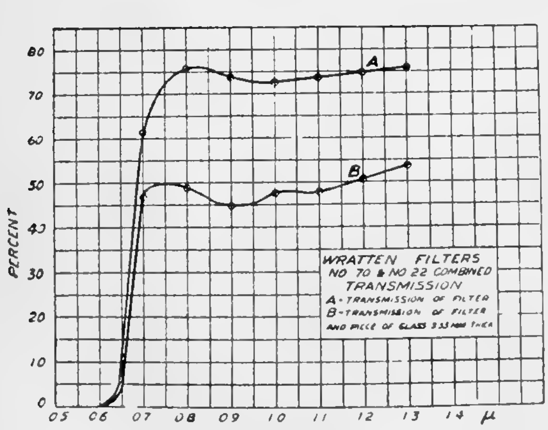

FIG. 11

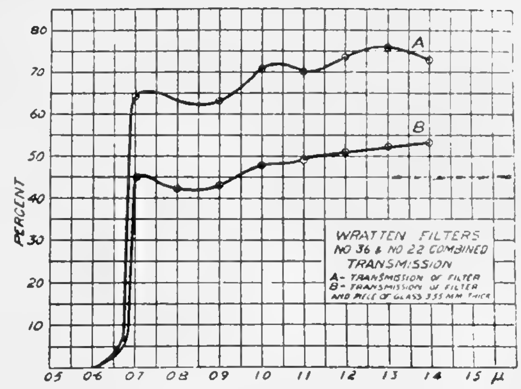

FIG. 12

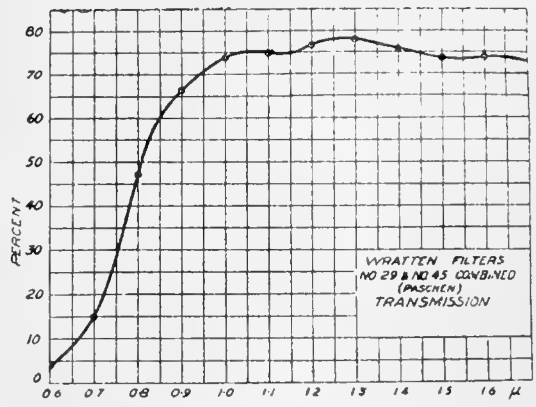

FIG. 13

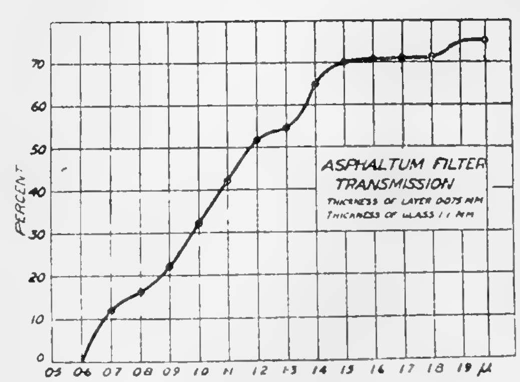

FIG. 14

corroborate the result obtained we made five new photographs of the mercury spectrum by means of a glass prism spectrograph. These are shown in Fig. 20. The source of the light used was a quartz mercury arc lamp which was operated with a current of about 4 amperes, under a potential difference of about 40 volts. The slit used was 0.2 mm. wide. The plates were stained with Dicyanin A.

Photograph (*a*) shows the mercury spectrum as obtained with an exposure of 1 minute on a panchromatic plate. The photograph has the usual appearance and extends into the red up to λ 6908A. The next (*b*) which was made on a stained plate with an exposure of 20 hours, is not so rich in lines as the first, but it shows already a slight trace of the line λ 10140A.

Next (*c*) with exposure of 40 hours showing very clearly the line λ 10140A has one very interesting feature. While all the strong lines appeared as black ones, two lines λ 6717A and λ 6908A are white. The fourth (*d*), taken with 60 hours exposure, has the two above mentioned lines turned black, and at the same time shows a line λ 7729A not previously registered. The fifth (*e*) photograph, although of 80 hours exposure, is more like the third (*c*); apparently some unknown cause reduced the intensity of the light and twice as long an exposure as in the case of (*c*) only compensated for this reduction of the intensity. Thus the last photographs clearly showed that the mercury line λ 10140A, as registered by Paschen[2] using a linear thermopile and galvanometer can be photographed and is one of the strongest lines in the mercury spectrum. It may be stated that in identifying the line λ 10140A a calibration curve, a reproduction of which is shown in Fig. 21, was made for the spectrometer. In making this curve wave-lengths commencing at λ4358A for mercury were used as ordinates and displacements in mms. on the photographic plates from the line λ 4358 were taken as abscissae.

An interesting point was brought out, namely that long exposures give white lines on the negative and black ones on the positive. This fact finds its explanation in the phenomenon noticed by Waterhouse and applied by Millochau[3] that infra-red rays destroy photographic action, on a plate which has previously been exposed to faint light. As the above photographs show it must be stated that visible rays possess this property too.

As to the plates used they had not been "solarized" but strong visible lines acting on the plate produce this "solarization," and later destroy it, appearing as white on the plate. Weak visible lines with

[2]Paschen, Ann der Phys., Vol. 27, p. 559, 1908.

[3]Millochau, Comptes Rendus, 144, 725, 1907.

FIG. 15

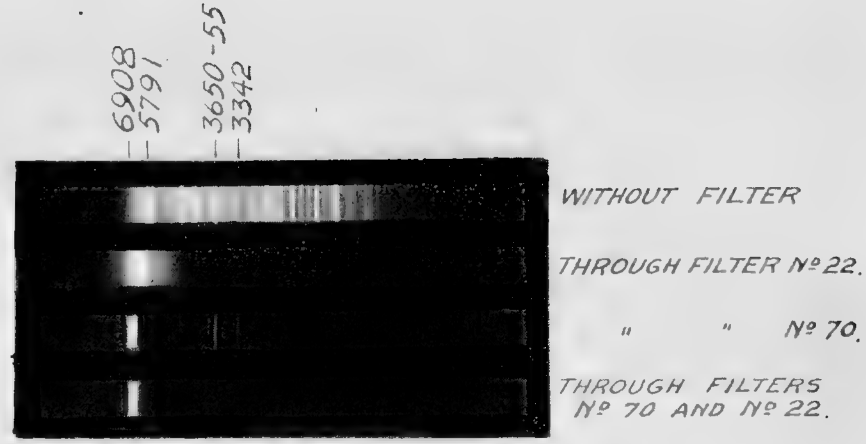

FIG. 17

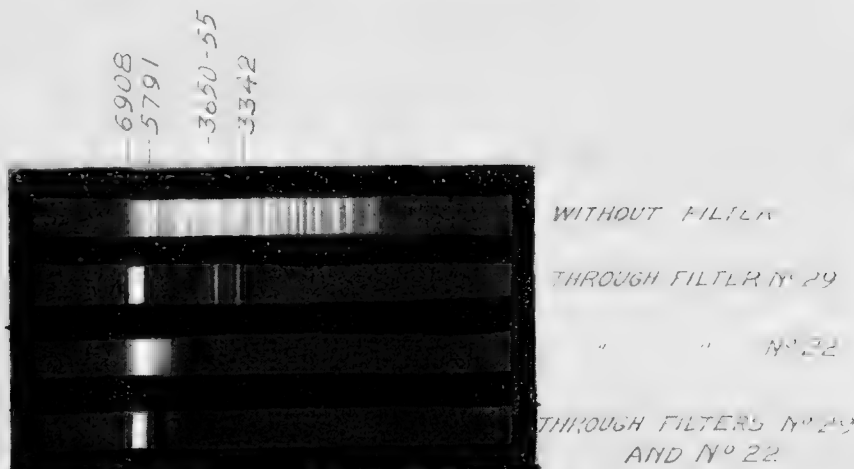

FIG. 16

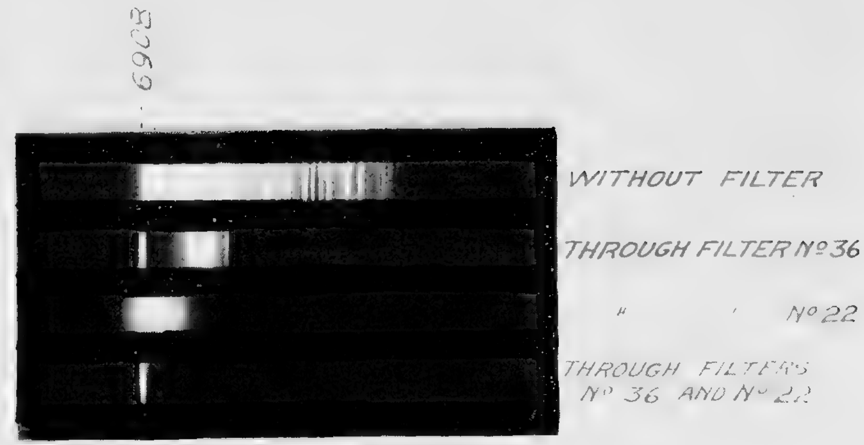

FIG. 18

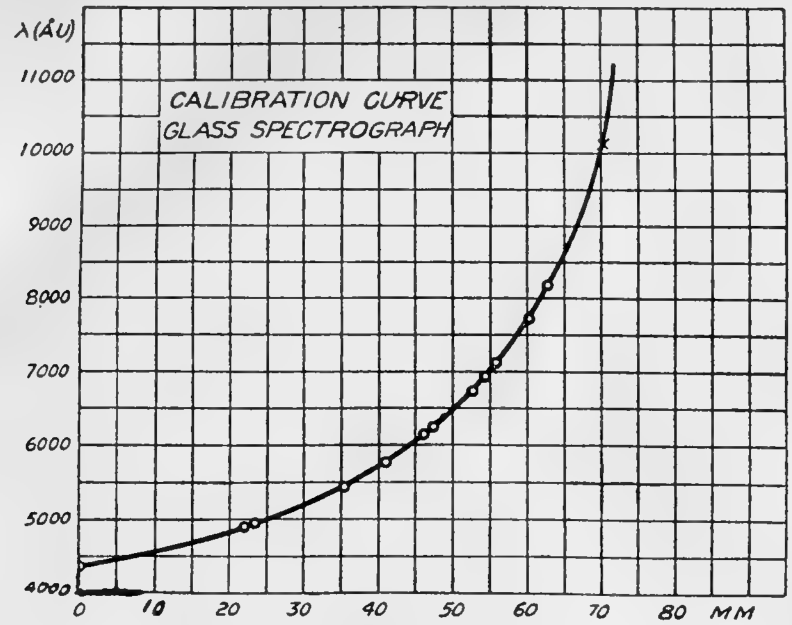

Fig. 21

considerably short exposure, as in the case of (*c*), appeared as usual, black, and longer exposure made them white too (*d*). Infra-red lines did not appear at all as black, being masked by the continuous background possessed by every gaseous spectrum, but the latter continuous background played a certain role, "solarizing" the plate, and as a result the infra-red lines appeared as white. Still longer exposures brought out more infra-red lines.

In the course of the work we tried to follow exactly Millochau's method, using malachite green instead of Dicyanin A and previously "solarising" the plates, but the results obtained were not so satisfactory as in the case of Dicyanin A, being used with no previous "solarization."

In concluding I wish to thank Professor McLennan, who suggested the problem, for his advice and assistance during the course of the experiment.

DIVISION II

By Miss E. M. Pearen

Part I. A Study of the Infra-red Spectrum of Mercury by Means of a Thalofide Cell

In the investigation of the infra-red spectrum of mercury by McLennan and Shaver[1] already referred to, it was shown that the

[1]McLennan and Shaver, Proc. Roy. Soc. A. Vol. 100, 1921.

spectrum could be recorded photographically at least as far up in the infra-red as $\lambda = 11137A$. It was also shown that intensity measurements on line spectra radiation could be made with considerable ease by the use of one of the thalofide cells devised by T. W. Case[2], of the Case Research Laboratory, Auburn, N.Y., U.S.A. The active part of such cells is a preparation of thallium-oxy-sulphide, fused on the surface of a quartz plate; the latter being securely mounted within an evacuated cylindrical flask about 2.5 cm. in diameter. Evacuation was found to increase the sensitivity of the cell and to prevent deterioration through oxidation. The thalofide cell has been found to be photoelectrically sensitive in the near infra-red region from $\lambda = 6000A$ to $\lambda = 12000A$. The sensitivity curve is given by Coblentz shows a sharp rise from $\lambda = 6000A$ up to $\lambda = 9000A$ and then a further rise to $\lambda = 10000A$. From this wave-length upwards the sensitivity falls off rapidly. The photoelectric sensitivity of these cells is brought into evidence by a lowering of the electric resistance of the active preparation when the latter is exposed to radiations comprised within the limits cited above. Though the cell has a maximum or specific sensitivity at or near $\lambda = 10000A$, it will be seen from the curve in Fig. 22 which was prepared for Professor McLennan by Mr. V. P. Lubovich from the spectro-photoelectric currents obtained with various wave-lengths in the radiation emitted by a 400 watt nitrogen filled incandescent filament lamp that the cell can be used with advantage for certain types of work within the spectral region .5 μ to 10 μ. For example, it was thought that it might be used to spot the wave-lengths in the infra-red grating spectrum of mercury though it was clear that the readings taken with it could not be taken directly as a measure of the energy associated with these wave-lengths. In this regard the thalofide cell is at a disadvantage compared with a linear thermopile.

To investigate this point the procedure adopted by McLennan and Shaver was followed. The grating used (with Eagle mounting) had a radius of one metre and a ruling of about 7.5 cm. with a total of 46,167 lines. Several photographs were taken of the first order infra-red spectrum of the light from a quartz mercury arc lamp bearing a current of about 4 amperes, the overlapping radiations from higher orders being cut off by the use of a Wratten filter known as No. 22. A reproduction of one of these photographs is shown in Fig. 24. From measurements on the lines of these plates the wave-lengths of the radiation producing the spectrum were deduced.

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[2]T. W. Case, Phys. Rev. (2), Vol. 15, p. 289, 1920.

When the thalofide cell was used it was mounted on the camera of the grating with its active surface in the focal plane of the latter. It was joined in series with a resistance of 240,000 ohms., a Tinsley galvanometer and a battery, the potential of which could be varied from zero to 80 volts. The slit of the spectrograph was about 1.8 mms. wide and a second slit about 8 mms. wide was placed directly in front of the cell to limit the radiation entering it from the grating.

The unilluminated thalofide cell with this circuit gave a steady "dark current" of about 330 mms. deflection when the potential difference applied was 40 volts. The deflections in excess of this dark current deflection were read with the cell illuminated, readings being taken at given intervals as the cell was moved along the focal plane of the grating. As the cell in any given position did not reach

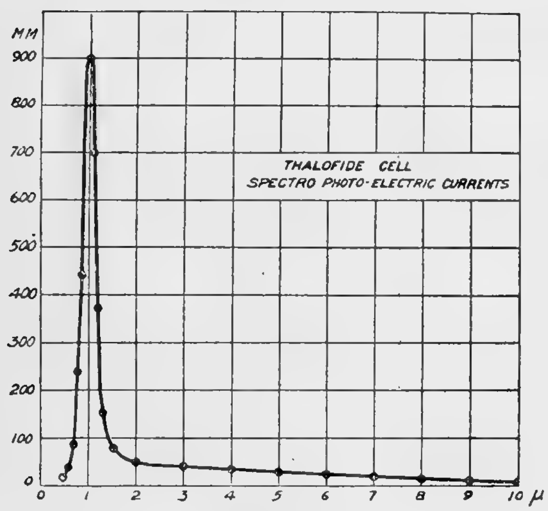


Fig. 22

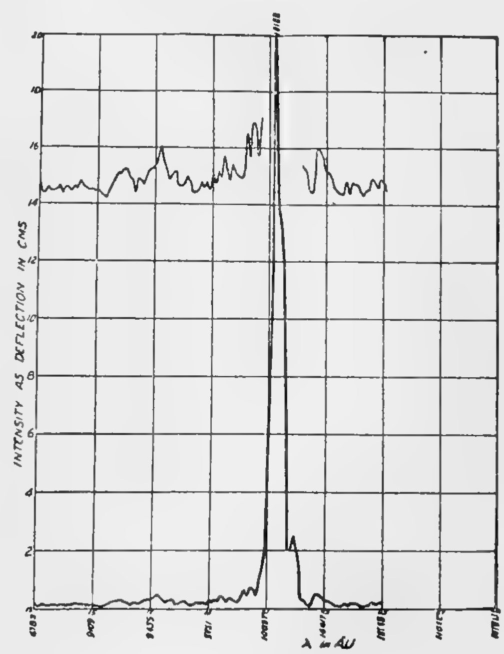


Fig. 23

a steady state at once, the reading was taken one minute after the commencement of each exposure. These readings have been plotted as ordinates in Fig. 23 and the wave-lengths used as abscissae are those obtained by calibrating the grating with the lines of the second order spectrum falling within the range investigated. It was assumed that each peak on the curve corresponded to a wave-length in the spectrum and on this basis the constitution of the latter was determined. The wave-lengths in the spectrum of mercury as deduced by the photographic method and by the thalofide cell method in the present investigation are given together with the determinations of the wave-lengths by McLennan and Shaver in Table I.

It will be seen that while there is agreement for five or six wave-lengths in the values found by the two methods there are a number of wave-lengths recorded photographically that were not detected by the cell method. Similarly a number of wave-lengths were detected by the cell method of which no trace was obtained photographically. It seems evident, too, both from the photographic record and the readings taken with the cell that the wave-length usually given at $\lambda = 10140A$ is in reality a combination of wave-lengths with strong members at $\lambda = 10121A$ and $\lambda = 10165A$.

Part II. Infra-red Spectra of Certain Metals

(1) *Introduction*

In this part of the investigation an attempt was made to study by the photographic method the infra-red spectra of tin, lead, bismuth, zinc and antimony.

While many of the early workers in spectroscopy had studied the infra-red spectra of various metals it is to such workers as Paschen and Randall that we are primarily indebted for accurate determinations of wave-lengths in the spectra of many of the elements in the near infra-red region.

Some notable work was done by Paschen[1] in 1909, partly with a bolometer and partly by photography, in the infra-red region extending up to $\lambda 28000A$. In the following year he extended his observations to λ 50000A. By phosphor-photography Lehmann[2] successfully measured a number of infra-red lines in the spectra of various metals. As regards the spectrum of bismuth it may be pointed out that experiments have been made on it by A. Kretzer,[3] that are worthy of special mention.

Extensive infra-red measurements (probably the most reliable and comprehensive of their kind, of recent date) have been made by H. M. Randall,[4] who examined the spectra of eleven elements in the region λ 7500A to λ 30,000A. A carbon arc was used as a source of light, the lower positive carbon having been bored out and filled with the material to be examined. The light was focussed by a quartz lens on the slit of the spectrograph which, including the concave mirror, Rowland grating and thermopile was enclosed in a thick walled chamber of brass. The thermopile used was of the Rubens

[1]Paschen, Ann der Phys. 29, p. 625, 1909; 27, p. 537, 29, 625, 33, 717, 1910.
[2]Lehmann, Ann. der Phys. 39, p. 53, 1912.
[3]Kretzer, Zeit. Wiss. Phot. 8, p. 45, Jan., 1910.
[4]H. M. Randall, Astrophys Jl. Vol. 34, No. 1, July, 1911.

type and the galvanometer a Paschen model. By this method he was able to locate a large number of infra-red lines hitherto unknown.

A number of lines found by Randall with the thermopile have been identified by F. M. Walters[5] by photography. An Anderson grating was employed for this work and Seed plates sensitized to long waves by staining with Dicyanin. A sample of the metal to be examined was inserted in a hole bored in one of two copper or graphite terminals, between which the arc was maintained, the lower electrode always being positive. The overlapping second and third orders were screened out by a cell of potassium bichromate or a piece of Jena red glass. The majority of the lines measured by Walters lie between λ 5000A and λ 9000A. It has already been noted that the limits of photography indicated by Meggers,[6] Kiess,[7] Merrill,[8] and McLennan and Shaver[9] may be as high as λ 11650A. As the only work attempted up to this limit for the materials tin, lead, bismuth, zinc and antimony has been done by Randall and as the work of Walters by the photographic method did not extend much beyond λ 9000A, an attempt was made by the writer to use the photographic method to confirm Walter's results in the region below λ 9000A, and Randall's results in the spectral region above this limit.

(2) *Preliminary Experiments, with Mercury*

Before proceeding to photograph the spectra of metals some experiments were carried out on the mercury spectrum in order to gain familiarity with the technique of the various operations. The grating spectrograph was set for the region λ 8000A to λ 11,000A, and the width of slit used was one mm.

The light used was obtained from a mercury arc lamp running on the 110 D.C. circuit and bearing a current of about four amperes. A Wratten Wainwright filter No. 22 was used to cut off the overlapping portions of higher orders. Ordinary rapid Seed plates sensitized to infra-red waves by Dicyanin were used. The plates were dyed according to the formula of Merrill,[10] the solution used being as follows:

Distilled Water	70 C.C.
Ehtyl Alcohol	60 C.C.
Dicyanin	3.5 C.C.
Ammonia	4.5 C.C.

[5]F. M. Walters, Bureau of Standards, No. 411, April, 1921.
[6]Meggers, Bureau of Standards, Vol. 14, p. 371, 1917.
[7]Kiess, Bureau of Standards, No. 324, p. 637, 1918.
[8]Merrill, Bureau of Standards, No. 318, p. 487, 1918.
[9]McLennan and Shaver, Proc. Roy. Soc. A., Vol. 100, 1921.
[10]Merrill, Bureau of Standards, No. 318, p. 487, 1918.

The Dicyanin, taken from a stock solution previously made, was poured into a well-shaken solution of distilled water and alcohol which had been allowed to stand for a few minutes. After being vigorously stirred and again allowed to stand for some time the ammonia was added. After a short time the solution was poured over the plate in a shallow tray. The plate was allowed to remain in the dye for 4½ minutes and was then placed in an ethyl alcohol bath for 40 seconds, after which it was dried in a current of cold air. It was necessary to perform all the operations in total darkness and throughout to maintain the solutions at a low temperature. With an exposure of thirty hours the wave-length $\lambda = 10140A$ came out clearly along with a number of others recorded by McLennan and Shaver.[11] As already stated, a reproduction is shown in Fig. 24.

(3) *Infra-red Spectra of Tin, Lead, Bismuth, Zinc and Antimony*

With arrangements identical to those used in the preliminary experiments above, investigations were undertaken on the spectra of tin, lead, bismuth, zinc and antimony. A carbon arc lamp was used, the lower electrode having been drilled out and filled with the metal to be examined. On account of the relatively low melting points of the metals used in this work it was impossible to employ electrodes of the metals themselves. The upper negative carbon was 1 cm. in diameter and the lower positive one 1.5 cms. In one case an arc was tried in which the upper electrode was a cylindrical copper rod[12] 1 cm. in diameter, and the lower electrode a copper plate about 7 cms. long, 3 cms. wide and 2 cms. thick. On this a small bead of the metal under test was placed, constant feeding being necessary. It was thought that this should bring out the enhanced spectrum more clearly but the final results were not as satisfactory as when carbon electrodes were used. The arc was fed from the 220 D.C. mains and carried a current of from 15 to 20 amperes. The lamp was placed so that the light fell on a concave mirror, and from it was reflected to the slit, no light passing from the arc directly to the slit. The average length of the arc was about 8 mms. and its image was kept upon the slit by adjusting the mirror in such a manner that the images of the carbons fell above and below the slit, through which, therefore, only radiations from the arc itself passed. An attempt was made to minimize the spectrum of carbon together with its impurities by keeping the positive electrode loaded with the metal under in-

[11]McLennan and Shaver, Proc. Roy. Soc. A., Vol. 100, 1921.
[12]G. A. Hemsalech and A. de Gramont, Phil. Mag., Feb., 1922.

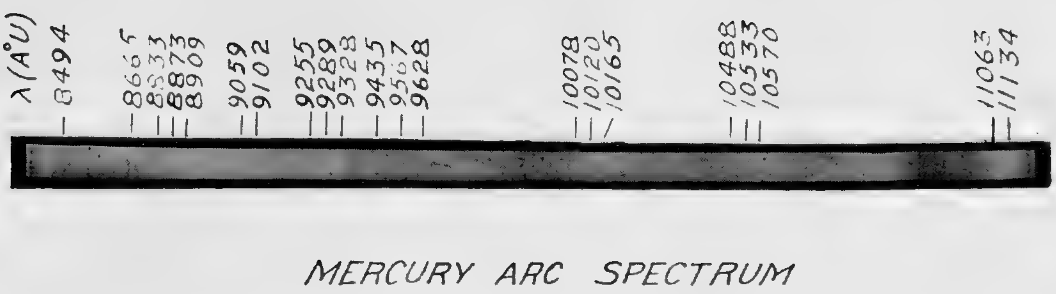

λ(A°U)
8494
8665
8833
8873
8909
9059
9102
9255
9289
9328
9435
9567
9628
10078
10120
10165
10488
10533
10570
11063
11134
MERCURY ARC SPECTRUM

Fig. 24

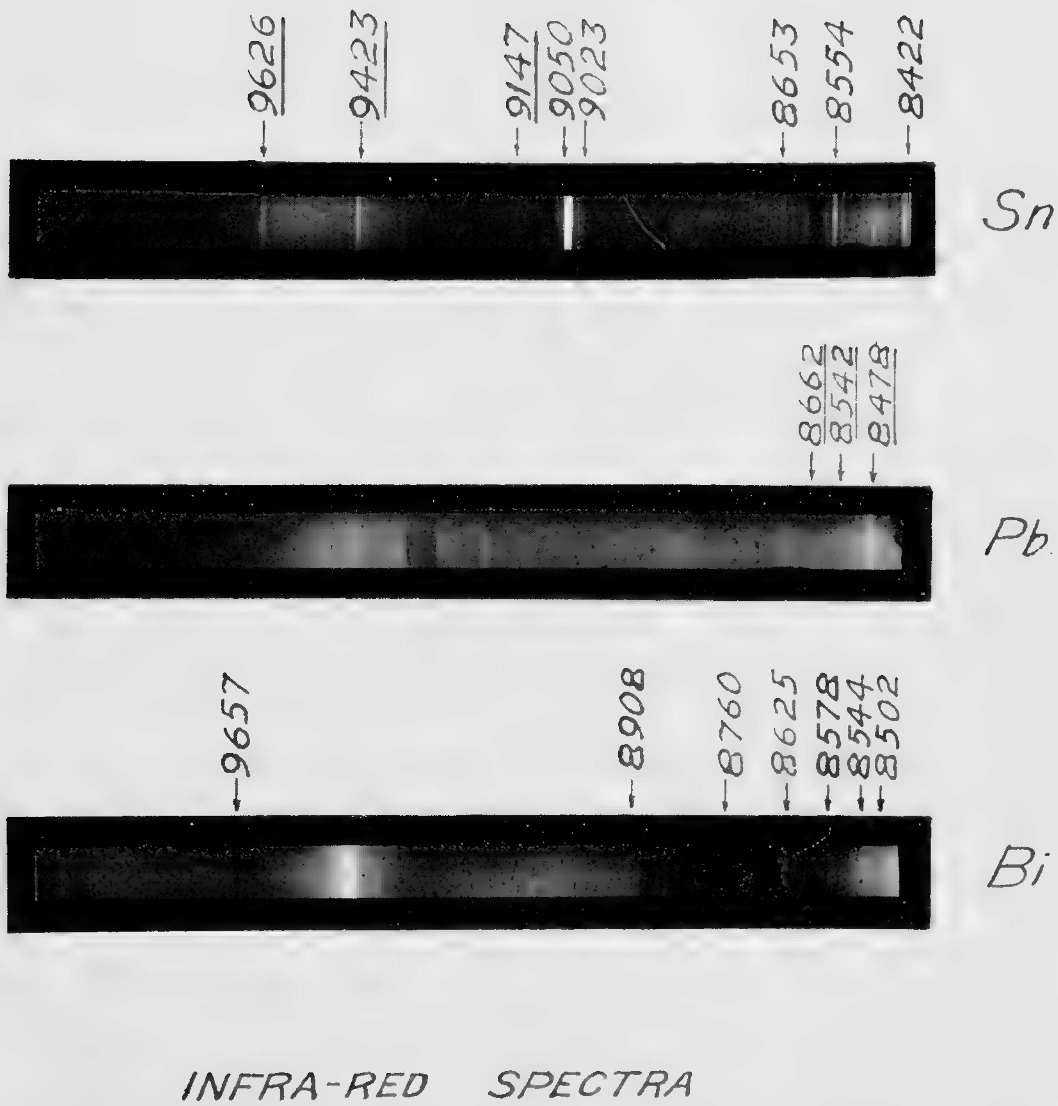

9626
9423
9147
9050
9023
8653
8554
8422
Sn
8662
8542
8478
Pb
9657
8908
8760
8625
8578
8544
8502
Bi
INFRA-RED SPECTRA

Fig. 25

WAVE LENGTHS FROM MERCURY ARC

PHOTOGRAPHY		THALOFIDE CELL	PHOTOGRAPHY		THALOFIDE CELL
McLENNAN & SHAVER	AUTHOR	AUTHOR	McLENNAN & SHAVER	AUTHOR	AUTHOR
ÅU	ÅU	ÅU	ÅU	ÅU	ÅU
8192					9826
	8490				9875
8605	3465		9914		
8710			9953		
8774		8773	9973		9995
8743			10037		
8852	8833	8832	10078	10078	
	8875	8897	10121	10120	10121
	8909		10165	10163	
		8930	10212		
		8978			10238
		9011	10300		
9025			10324		
9057	9059				10368
	9103		10377		
9217		9218	10413		
9233	9233		10433		
9288	9239	9236	10485	10488	
9327	9329	9327	10531	10533	10531
	9435		10567	10570	
9439					10678
		9477			10729
9487			10883		
9510			11053		
		9549		11063	
9565	9567		11089		
9597			11101		
		9624		11134	
9628	9628		11137		
		9696			
9710					
		9718			
9755		9737			
		9743			

TABLE I.

BISMUTH

WALTERS	RANDALL	AUTHOR	WALTERS	RANDALL	AUTHOR
ÅU	ÅU	ÅU	ÅU	ÅU	ÅU
5552·35			9058 62	9059 5	
5599 41			9342 60	9344 1	
5718 81			9657·20	9657 9	9657
5742·55				9828 8	
6134·82				10106 1	
6184·99				10304 7	
6364 75				10540 2	
6475·73				11073 2	
6476·24				11555 5	
6991·12				11711 9	
7036 15				11994 5	
7335·01				12166 5	
7441 25				12690·5	
7502·33				14331 5	
7838·70				22554·2	
7840·33	7841 1				
8210·83					
8501 8		8502			
8544·54		8544			
8579 74		8578			
8627 9	8628 5	8625			
8754 88					
8761·54	8761 8	8760			
8907 81	8910 0	8908			

TABLE 4.

TIN

WALTERS	RANDALL	AUTHOR	WALTERS	RANDALL	AUTHOR
ÅU	ÅU	ÅU	ÅU	ÅU	ÅU
6924 72				9414 9	
7685·29					9423
7754·94				9619·4	
7809 75					9626
8100·42				9746·0	
8114·06		8114		9808 7	
8121 42				9852·5	
8249·6				10458·6	
8338 0				10808 8	
8345 38				10896·0	
8349 55				11194 0	
8357 05				11279·2	
8391 27				11339·2	
8422 77		8422		11457·3	
8457 6				11618·0	
8552·6	8554·7	8554		11672 6	
8649 2				11741·9	
		8653		11827·2	
8681·4				11935·3	
8709·9				12982 9	
8806·61				13022 0	
8908·11					
9018·9					
9023·1	9023·2	9023			
9145·3		9147			

TABLE 2.

ZINC

WALTERS	EDER & VALENTA	AUTHOR	WALTERS	EDER & VALENTA	AUTHOR
ÅU	ÅU	ÅU	ÅU	ÅU	ÅU
5772 64				7664 84	
5775 94				7698 43	-
5777 81			7799 04		
5894 38				7932 95	
6183 97				7937 93	
6214 62				8116 74	
6237 82				8144 57	
6239 14				8161 01	
6362 34				8186 65	
6478 84				8187 38	
6928 69				8198 85	
6938 77				8202 91	
6943·55				8241 50	
	7026 07			8253 46	
	7264 22			8255 76	
	7338 88				8904
	7356 45				8944
	7358 54				9056
	7361 35				9264
	7363 11				9360
7468 44					9444
7478 71					9620
	7578 75				
	7624 77				

TABLE 5.

LEAD

WALTERS	RANDALL	AUTHOR
ÅU	ÅU	ÅU
5608·85		
5692·26		
5895·70		
6002 24		
6011 98		
6059 71		
6110 70		
6169 40		
6235·44		
6660 37		
7099 78		
7229 11		
7330 12		
8272·85		
		8478
		8542
		8662
	10292 9	
	10501 3	
	10650 8	
	10888 6	
	10971·5	
	12563 8	
	13101·9	
	14744·4	
	15315·6	

TABLE 3

ANTIMONY

WALTERS	RANDALL	AUTHOR	WALTERS	RANDALL	AUTHOR
ÅU	ÅU	ÅU	ÅU	ÅU	ÅU
6738 99					8494
6778 38			8572 59		8572
6806 35			8619 60		
6811 42			8682 88		
6995 91			8700 20		
7006 19			8719 79		
7032 88			8735 0		
7122 28			8789 2		
7136 29			8860 2		
7222 50			8903·1		
7362 30			9019 5		9018
7405 50			9132 30		
7442 0					9448
7592 82				9519 9	
7648 28				9930 5	
7755 85				10029 9	
7764·9				10262·9	
7816 9				10587 2	
7834·6				10678 6	10680
7837 25				10742 9	
7844 44				10840 6	
7867 17				10880 3	
7906 73				11013 4	
7924 65				11082 7	
7933 38				11109 7	
7969·47				11190 3	
8062·1				11268 5	
8241 74				11864·3	
8257·52				12178·9	
8289 0					
8314 21					
8411 65		8412			

TABLE 6.

vestigation and so making sure that the arc stream was always charged with the vapour of the element. When this condition existed the arc made a loud hissing sound, and also showed a colour in the core, that was more or less characteristic for each of the metals used. If the arc burned more quietly and showed that the undesirable spectrum of carbon was being produced, the circuit was broken, the carbon freshly charged, and the arc again struck.

Under these conditions photographs were taken of the spectra of tin, lead, bismuth, zinc and antimony. The exposures were all of fifteen hours duration with the exception of bismuth, which was given an exposure of forty hours.

In order to make an accurate measurement of the wave-lengths a photograph of the ordinary mercury spectrum in second order was taken on each plate for purposes of comparison. The plates were carefully measured with a vernier microscope and the lines identified are given in Tables II, III, IV, V and VI. All the lines identified by Walters and Randall between $\lambda = 5500A$ to $\lambda = 22000A$ are given as well for comparison although in the present series of experiments only the region between $\lambda = 8000A$ to $\lambda = 11000A$ was investigated. The reproductions shown in Fig. 25 are typical of the results obtained.

In conclusion acknowledgment is made to Professor J. C. McLennan for his interest, encouragement and his many valuable suggestions in this work, as well as to Mr. V. P. Lubovich for occasional assistance in technique.

The Physical Laboratory,
University of Toronto.
June 1st, 1922.

A Method of Detecting Electrical and Magnetic Disturbances

By BROTHER PHILIP, M.A., F.S.C.

(Presented by J. PATTERSON, F.R.S.C.)

During the World War Professor J. C. McLennan, Ph.D., F.R.S., of the University of Toronto, in the course of his investigations with submarine cables, found induced in them stray currents which became especially strong during thunder storms and which seemed to have a directional effect. Pressure of other work prevented their being investigated at the time; and at his suggestion, the present writer undertook the investigation in colloboration with the Meteorological Department, and under the direction of Mr. Patterson of that department. The object was to record the various currents induced in a coil of large diameter, to identify them, and, if possible, to correlate them with meteorological, magnetic and other conditions.

Description of the Apparatus

The apparatus consisted essentially of a long cable laid directly on the ground around a nearly rectangular field, having a perimeter of 2,580 feet. The cable was formed from six strands of rubber insulated copper wire enclosed in a lead sheath and connected to form a continuous circuit; a pair of leads, each 419 feet long, were brought to the recording apparatus. Thus the total length of wire through which the current passed was 16,318 feet, or about 3.09 miles.

The house in which was kept the recording apparatus was midway between the coil and the Toronto and York Radial line, and 450 feet from each. The leads connected to a galvanometer of the Ayrton type with photographic registration and having a resistance of 42.3 ohms, and figure of merit 5.4 by 10^{-8}; the resistance of the field coil was 55.65 ohms. To keep the deflections of the galvanometer on the scale a high resistance was used in series, so that observations could be made either by the eye or automatically on bromide film, 8 cms. wide. This film was fed by clock-work at the rate of 8 cms. an hour, when an automatic arrangement cut off the light for a short time.

Inside the photographic box was a stationary mirror to act as a base line on the film. Both the mirrors were of focal length 50 cms. so that the galvanometer deflections could be accurately estimated in milliamperes. A deflection of 10 mms. on the film corresponded to one milliampere with a resistance of one ohm in circuit; thus it was an easy matter to change from linear measurement to electrical constants.

The cable was laid on December 15, 1920. At different times of the day from December 23, 1920, to February 8, 1921, readings were taken for periods averaging half an hour, from which the following was ascertained:

(*a*) The approach, or passing, starting or stopping of a trolley car, even though close by, seemed to have no appreciable effect on the deviations.

(*b*) The deflections were both positive and negative and of almost equal occurrence in both directions.

(*c*) The larger deviations, those of the order of 1 milliampere, averaged about 1 a minute, though they varied continuously, and sometimes 15 or 20 occurred in a minute.

(*d*) Weather conditions seemed to have no effect on the deflections, which could be correlated with either temperature, pressure, wind or humidity.

The recording instrument in its final form was set up towards the end of March, 1921, and a continuous record was taken till May, 1922.

Influence of the Radial Line

The proximity of the Radial Line was a most important factor, as shown by Fig. 1, which is a comparison between the power line kilowatt load curve and the earth current record. Both scales are nearly identical; the two upper traces show the ordinary night forms of the curves: the kilowatt load curve, *A* indicated by the arrow, being nearly a straight line at the top of the trace, and the earth current record, curve *B*, showing a pronounced wave train of three waves from 12.30 a.m. to 2.00 a.m. The two lower curves are the ordinary day forms of the power line, *D*, and the earth current record *C*. From this it will be seen that it was an almost impossible task to eliminate from the electric and magnetic disturbances it was desired to study, those caused by the power line. Yet it was impracticable to place the cable in a convenient location free from power line effects.

Eye Observations of a Thunder Storm

Many attempts were made to get eye readings, using an auxiliary light, during the intervals when the power was off; but as these were rare and brief, the observations were few. As an instance, on April

7th, 1922, at 6.45 p.m., during the course of a moderate thunder storm, when the power was off for about five minutes, several eye readings were taken. At first the galvanometer was exceptionally quiet for three minutes even when its series resistance was cut out. Then apparently flashes of lightning occurred in the distance, for several violent deflections were noticed after a resistance of 1000 ohms was introduced in the circuit. Only after 50,000 ohms resistance was put in could readings be taken. One deflection of the needle showed a current equivalent to 60 milliamperes through one ohm. Of course such deflections were extraordinary and would be too violent and too fast to be recorded on bromide paper.

Type of Curve Caused by Earth Currents

Most of the records were so masked by power line effects that decisive evidence could only be obtained for one type of curve. This was a slow steady deflection with a period ranging from 30 seconds to 8 minutes, generally during an interval free from deflections of other types. Such deflections are only recorded on the autographic film, as they take place too slowly to be detected by the eye.

The decisive clue to the interpretation of these curves came during the remarkably intense and prolonged magnetic storm of May 11th to the 18th, 1921. During this period the records were altogether different from those hitherto obtained; there was hardly any difference between the day and the night traces, except that the latter were more vigorously disturbed, especially during the height of the magnetic storm. A careful comparison with the magnetic records showed an almost absolute agreement both as to time and value in the two curves. The type of curve obtained on this occasion is shown in Fig. 2, together with the horizontal force record obtained at the Magnetic Observatory, Agincourt, during the height of the magnetic storm. On the upper or magnetic record is shown the trace for two days, May 14 and 15, 1921, though the greater portion of the record for the 14th was off the scale; below are shown the corresponding earth current records. The time scale on the latter is much more open than that on the former and corresponding points are marked I and II. The similarity between these records is at once apparent. The earth current record shown here is quite different from the ordinary day form. Repeatedly the deflections of the type observed during the magnetic storm have come into prominence though, of course, with less intensity, and the agreement is always noted.

The Cable Used as a Loop for the Reception of Radio Waves

As an experiment the cable was connected directly to the aerial and ground binding posts of a vacuum tube receiving set; the galvanometer and high resistance were, of course, out of the circuit. Thus the cable acted merely as a huge loop aerial of high inductance. When using a detector and a two step amplifier several wireless stations were heard quite easily. The circuit seemed to function best for long waves, 13,000 to 20,000 metres, but waves of higher frequency were also received without difficulty. Though the receiving set was connected up only for a short time, ten or more stations were heard, some of them on the Atlantic sea-board. The radio broadcasting station of Schnectady was heard quite plainly, though the speech and music were somewhat distorted. The remarkable feature was that there was practically no static heard, even when using the second stage of amplification on long waves, despite the fact that the static was very bad when the receiving set was used some two hours after on an aerial of the ordinary type. As absolutely no precautions had been taken for the insulation of the cable, which was lying on the ground, partially covered with mud, water and snow, the strength of the signals was quite remarkable.

Summary

In the loop were induced currents of various sorts—power line currents, earth currents, currents due to changes in potential, in magnetic force, and finally, radio-frequency waves. These currents are continually flowing in the cable and vary considerably in magnitude; those manifestly due to magnetic storms are noted every day, though sometimes they are very faint.

Acknowledgment

The author begs to acknowledge his deepest obligations to Sir Frederick Stupart, Director of the Dominion Meteorological Office, who generously lent the requisite apparatus, and to Mr. John Patterson, who smoothed out all the practical difficulties, and without whose continual help and valuable advice little would have been accomplished. To these friends and to those not mentioned, but whose services were of great value, most heartfelt thanks are due.

FIG. I

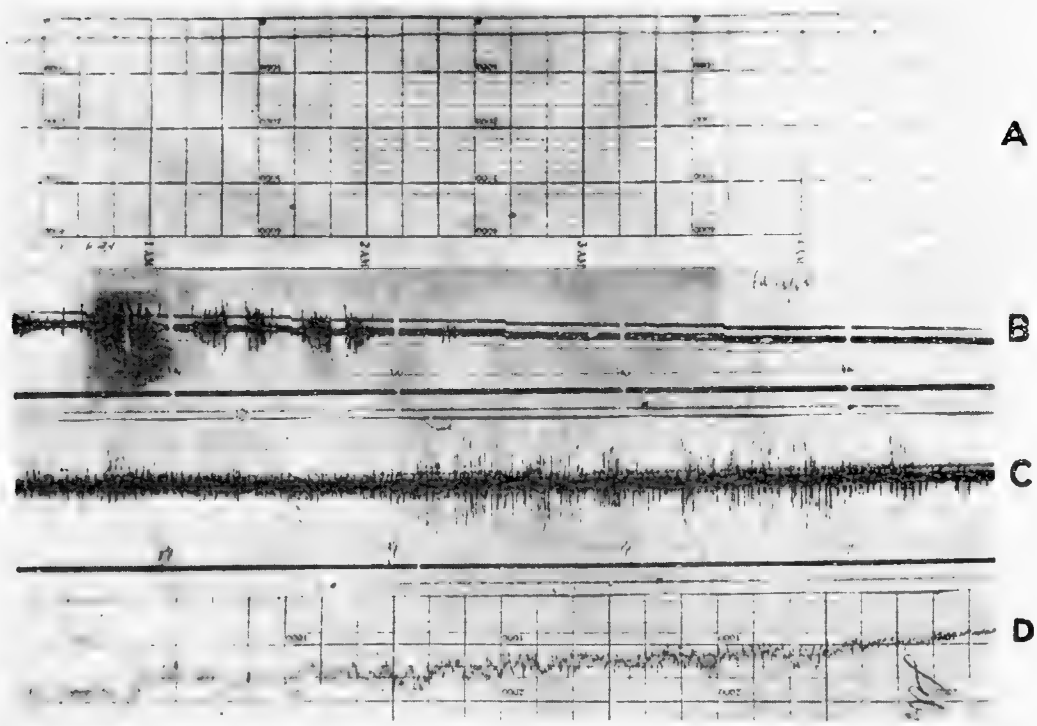
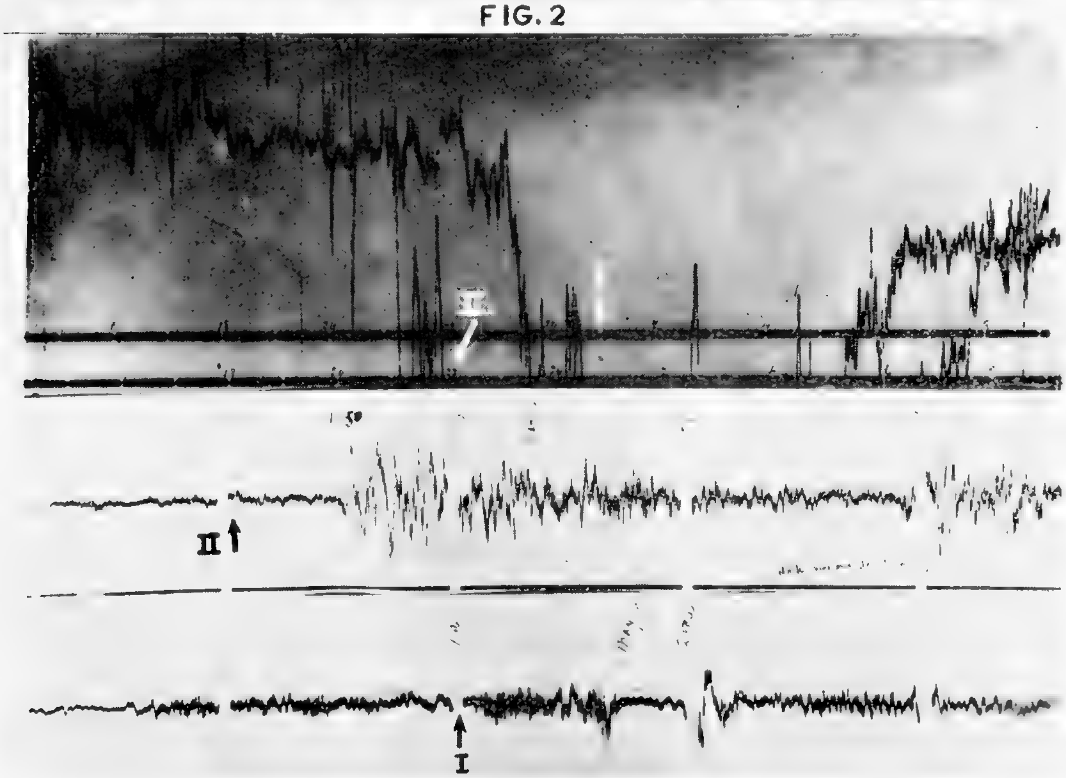


FIG. 2



On the Depression of the Centre of a Thin Circular Disc of Steel under Normal Pressure

By STANLEY SMITH, M.A., B.Sc.

Presented by PROFESSOR R. W. BOYLE, F.R.S.C.

(Read May Meeting, 1922)

The theory of the bending of a thin circular disc by the application of a normal pressure leads, in the important case of a maximum depression of the centre comparable with the thickness of the disc, to a series of differential equations which are not directly soluble.

In connection with some work the author is carrying out for the Associate Air Research Committee of Canada on the bending of aneroid and barograph diaphragms an attempt was made to find some empirical relation between the various quantities involved in the bending of a flat circular disc of steel. The disc, which was made of stainless steel kindly provided by Messrs. Thos. Firth, Ltd., was of fixed diameter, 6.14 cms., and of uniform thickness, .4 mm. It was first supported, edge-free, on a flat annular flange (concentric with the disc) of width 4 mms., the inside diameter of which was 4 cms. The supporting flange formed part of a chamber which, when the disc was in position, could be exhausted to any given pressure below atmospheric pressure, so that the disc could be subjected to pressure differences between its faces varying from zero to the barometric pressure, the area of the plate exposed to this pressure difference, p, being in the first instance a circle of diameter 4 centimetres. The values of p were measured on a U-tube mercury manometer by means of a cathetometer reading to .1 mm. The inside diameter of the manometer tubes was 1.85 cms. so that surface tension effects were negligible enabling p to be measured with a maximum possible error of .4 mm. In order to measure the depression, w, of the centre of the disc a light aluminium pillar, A (Fig. 1) was attached by shellac to the centre of the top surface of the disc and perpendicular to it. To A was attached a small round brass rod, B (Fig. 2), of length 8.5 mm. and diameter 3 mms., which operated the forked lever L by means of adjustable steel pivots E and F working in jewelled bearings C and D set in B. L was fixed rigidly to a brass rod K of length 9.8 cms. and diameter 3 mms., which could rotate about the steel pivots G and H working in jewelled bearings M and N set in K. A small concave

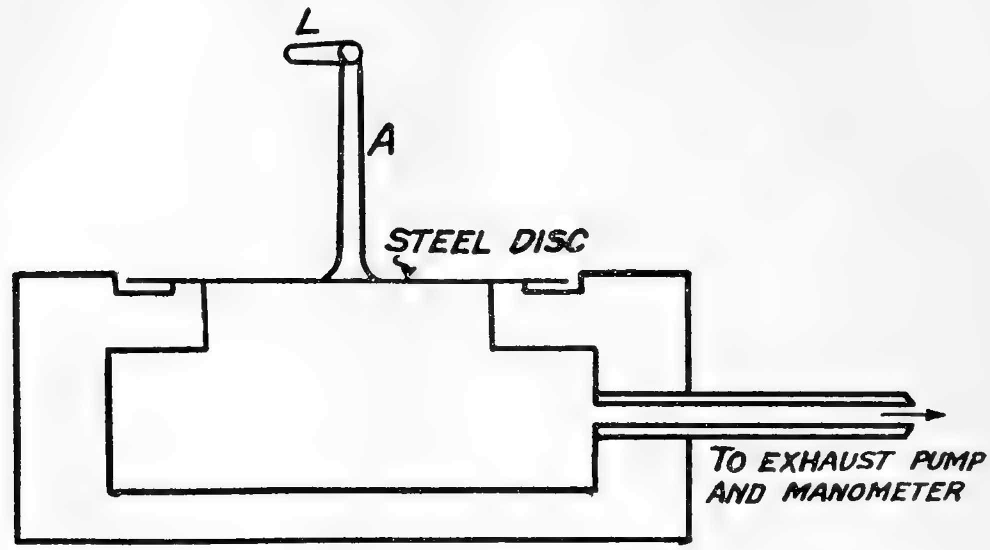


FIG. 1.

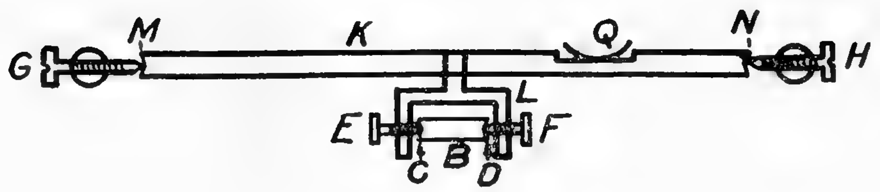


FIG. 2.

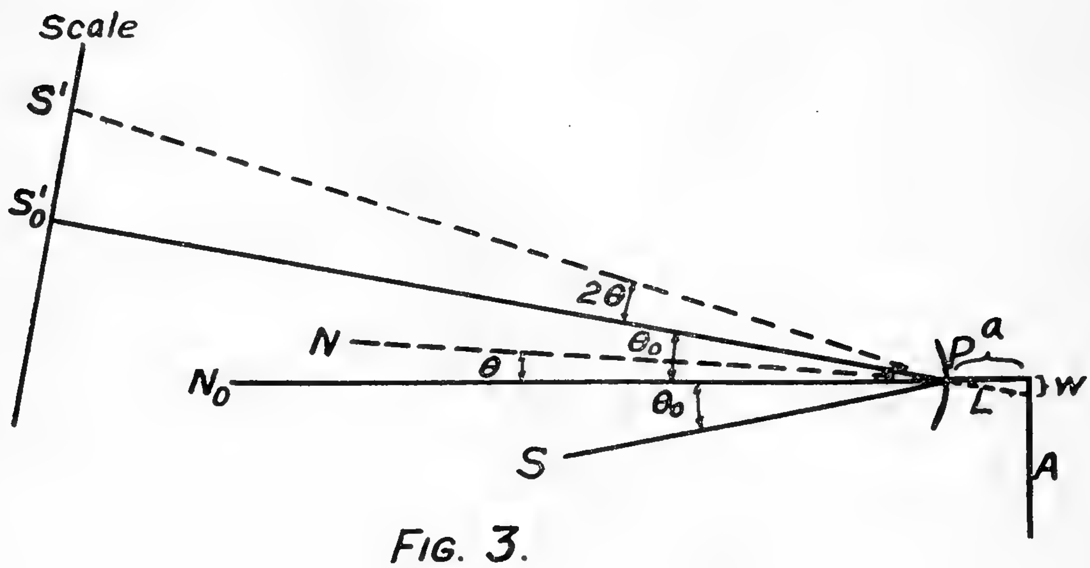


FIG. 3.

mirror Q, of focal length about 50 cms., was attached to K so that its pole was on the axis of rotation of K and its principal axis set perpendicular to the axis of K. A carbon filament lamp was placed in front of Q at such a distance from it as to project an image of a selected horizontal portion of the filament on to a scale situated 275 cms. from the mirror.

In figure 3 P is the pole of the mirror, PN_0, the principal axis, S is a point source of light on the filament and S_0' is its image on the scale before the centre of the disc is depressed. PS_0' was arranged to be perpendicular to the scale, the lever L being in this case perpendicular to A, i.e., perpendicular to the direction of the subsequent depression.

Denote the initial angle of incidence of the ray SP by θ_0. Then angle N_0PS_0' is also equal to θ_0. Now suppose the centre of the disc is depressed a distance w cms. The mirror is rotated about P through an angle θ such that $\sin\theta = \frac{w}{a}$, a being the length of the lever arm L in centimetres.

The angle of incidence of SP is increased to $\theta+\theta_0$ and the reflected ray strikes the screen at S' making angle $S_0'PS'=2\theta$.

If s is the scale deflection in centimetres then $\tan 2\theta = \frac{s}{b}$ where b is the distance of the scale from p.

For small angles of deflection $2\theta = \frac{s}{b}$ and $\theta = \frac{w}{a}$ hence $w = \frac{a}{2b} \cdot s$.

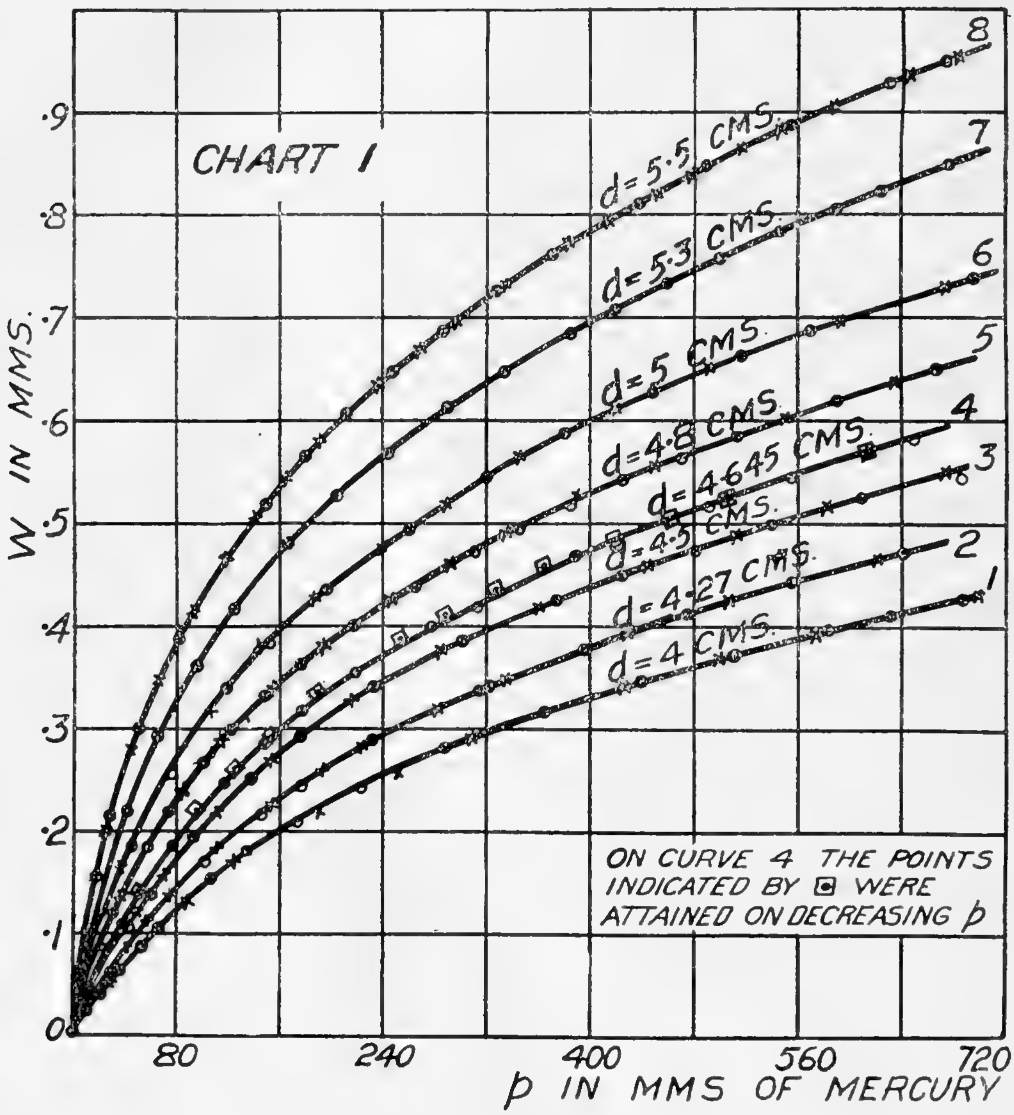
In the experiments $a = .88$ cms.; $b = 275$ cms.

hence $w = .0016\ s$.

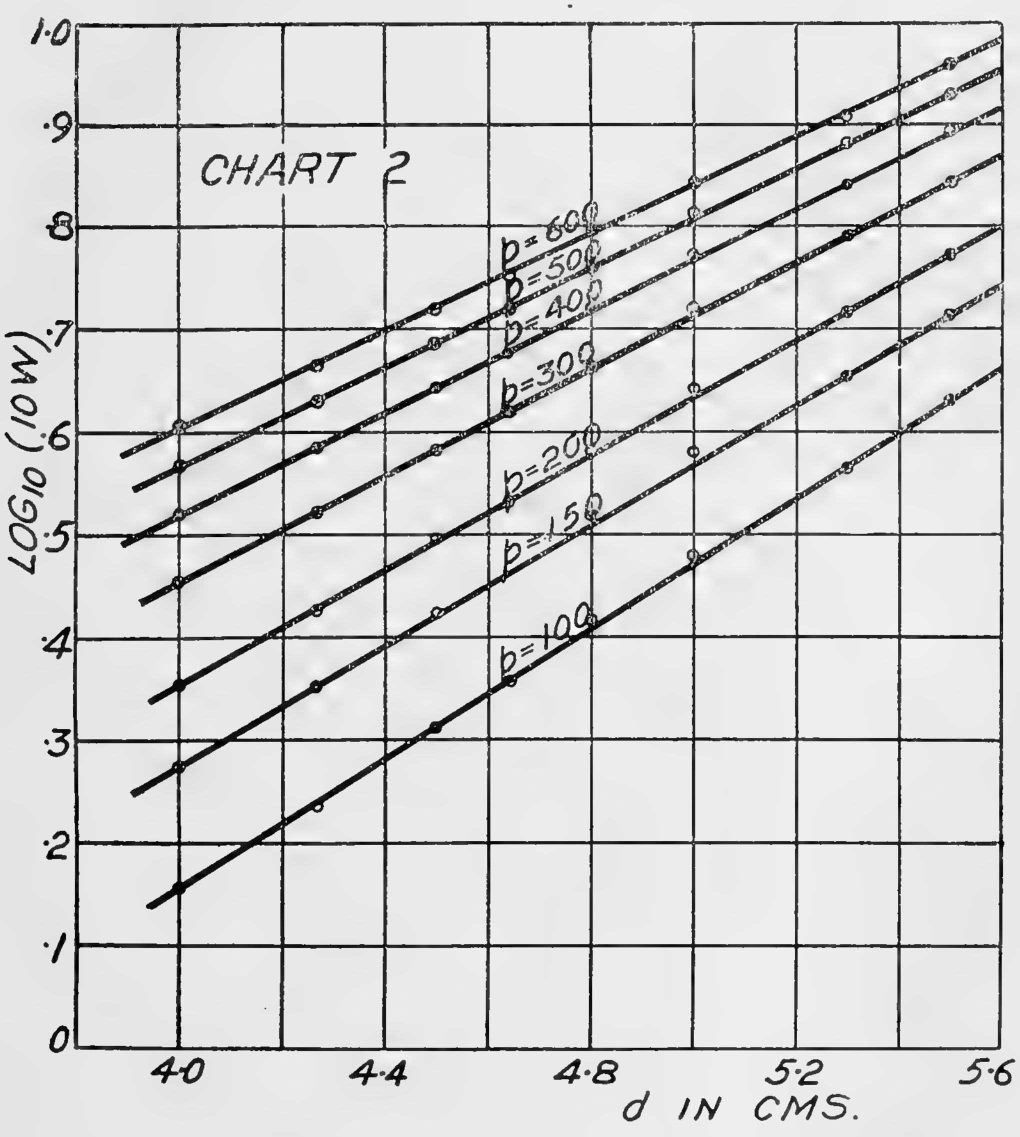
or $s = 625\ w$.

Thus the arrangement multiplies the depression by the factor 625. This, together with the fact that the friction effects are very small, enables the depression at the centre to be measured with a high degree of accuracy. In evaluating the values of w from the observations the relation $w = .0016s$ was used for scale deflections below 40 cms. but for larger deflections than this θ was first obtained from $\tan 2\theta = \frac{s}{b}$ and the value of w calculated from $w = a\sin\theta$. The first observations as mentioned above were carried out with a circular portion of the disc of diameter 4 cms. exposed to the pressure difference p, this circle being concentric with the disc itself. The diameter, d, of the exposed area was then increased successively to 4.27, 4.5, 4.65, 4.8, 5, 5.3, 5.5 cms. and the depressions measured for a number of values of p from zero to about 700 mms. of mercury. In each case a thin layer of vacuum tap grease was placed on the flange before the disc was put in position for the purpose of making an air-tight contact. The flange had a width in each case of about 4 millimetres.

It was expected at first that the presence of grease between the flange and the disc would give erratic values of the scale readings, and hence erratic values of *w*, but it was found that after the disc had been subjected to a large pressure difference and then brought

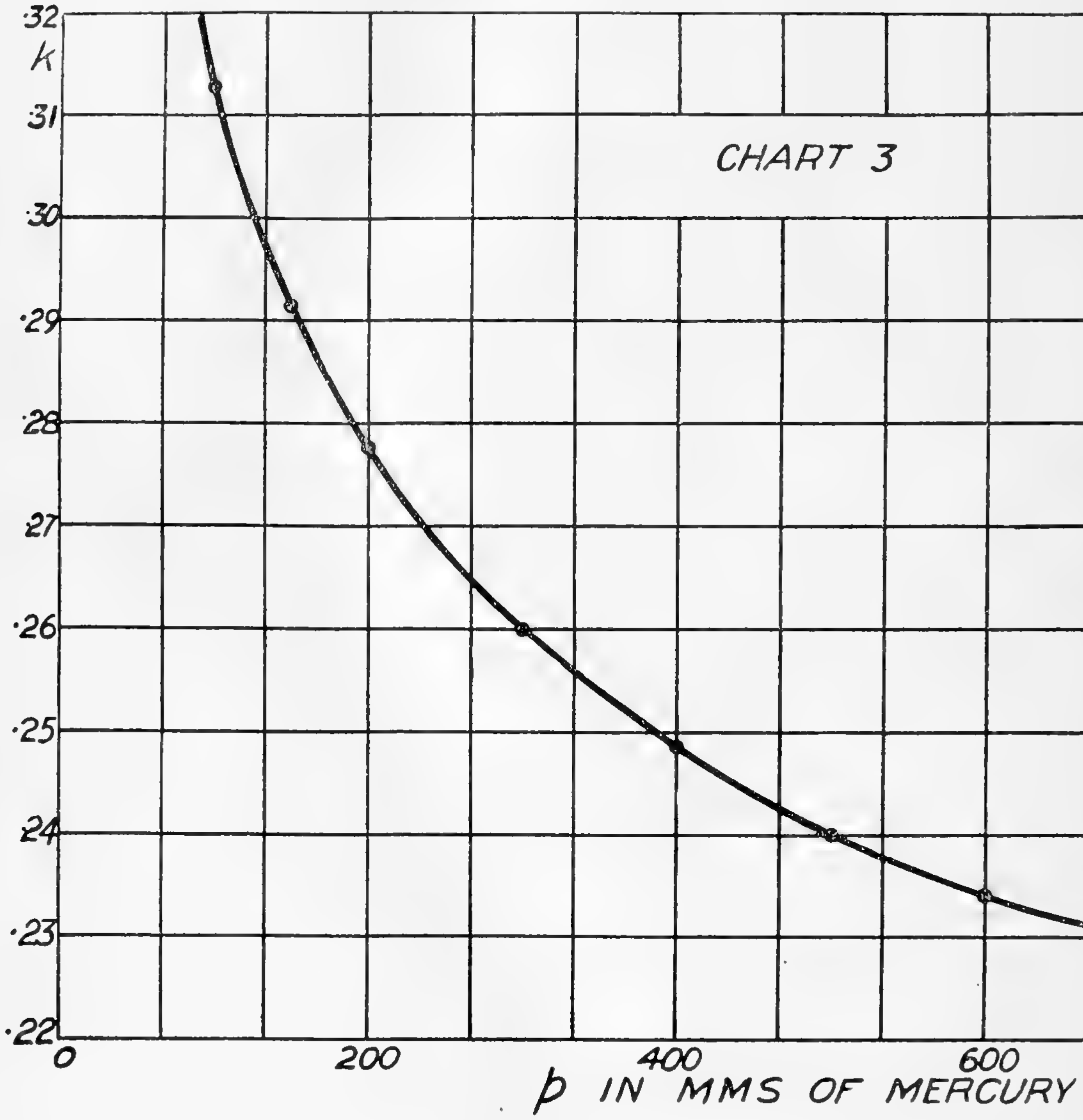


back to its unstressed condition any subsequent cycle of variations of *p* gave a *w-p* curve for decreasing *p* which was practically coincident with the *w-p* curve for increasing *p*. A typical example is shown in the case of curve 4 on chart 1. The slightly larger value of *w* on descent as compared with the value of *w* for the same value of *p* on ascent may be due to one or both of two causes, viz., back lash and elastic fatigue of the steel. If the discrepancy is due to elastic fatigue it will not affect the curves as they were all taken for increasing p, and if due to back lash the effect is small enough to be neglected. The important point is that after the disc had been subjected to a sufficiently large pressure difference the grease was apparently forced to assume a permanent configuration and does not affect the subsequent values of the scale deflections.



Tables I and II contain the values of p and w for some of the observations. The results of all the observations are plotted on Chart 1.

It was found that, if for a given value of p, log w was plotted against d, a straight line relationship was obtained. On chart 2 are plotted the values of $\log_{10} (10w)$ against d for seven values of p, viz., 100, 150, 200, 300, 400, 500 and 600 mms. of mercury. Values of $\log_{10} (10w)$ were taken to avoid negative characteristics. It is seen that the points lie on a series of straight lines, the slopes of which decrease with increasing values of p. These straight lines would appear to belong to a concurrent system as they all intersect at approximately the same point. The mean position of the points of intersection has been taken. It was found to have co-ordinates (9.7, 1.94) so that the system of straight lines may be expressed as $1.94-\log_{10}(10w)=k(9.7-d)$ where k is the slope and is a function



of p. k was then calculated for different values of p and k plotted as a function of p. This relation is given by the curve on chart 3.

By means of the equation

$$1.94-\log_{10}(10w)=k(9.7-d) \tag{1}$$

and the (k, p) curve the depression of the centre of the disc can be evaluated for any value of p between 0 and 700 mms. of mercury and any value of d between the limits 4 and 5.5 cms.

TABLE I

d=4 cms.		d=4.27 cms.		d=4.5 cms.		d=4.65 cms.	
p in mms. of mercury	w in mms.	p	w	p	w	p	w
9.5	.020	23.5	.056	31.0	.087	36.0	.109
17.9	.039	44.1	.092	60.7	.136	66.4	.170
33.8	.064	69.8	.131	92.5	.194	90.5	.212
65.2	.104	97.5	.167	136.9	.252	129.4	.266
85.4	.129	139.6	.212	176.2	.292	156.1	.298
110.5	.154	169.3	.240	232.3	.340	186.2	.327
138.5	.181	238.4	.293	294.8	.381	222.2	.358
176.3	.212	320.7	.341	367.9	.421	268.7	.394
228.4	.245	399.9	.381	419.1	.447	302.2	.417
288.9	.282	466.5	.410	475.6	.472	345.3	.444
309.2	.291	558.2	.444	540.8	.498	385.8	.467
364.6	.318	644.2	.474	604.9	.523	432.0	.490
439.1	.349	.....	....	669.1	.543	496.8	.520
507.0	.374	.....	....	.....	....	557.3	.547
583.2	.399	.....	....	.....	....	596.4	.562
630.0	.414	.....	....	.....	....	674.5	.592
687.5	.430	.....	....	.....	....	.....	....

TABLE II

d=4.8 cms.		d=5 cms.		d=5.3 cms.		d=5.5 cms.	
p	w	p	w	p	w	p	w
31.1	.122	14.7	.076	17.5	.127	19.4	.157
57.1	.184	44.7	.184	42.1	.220	30.2	.215
74.7	.218	76.3	.259	66.2	.294	46.9	.281
101.2	.265	119.3	.340	96.0	.361	65.2	.341
124.5	.298	153.2	.386	127.2	.418	92.6	.412
151.5	.332	197.1	.436	169.5	.483	119.1	.463
178.0	.361	257.5	.495	206.3	.530	141.4	.507
218.9	.400	320.8	.543	245.1	.568	162.4	.535
264.7	.438	384.0	.587	292.3	.614	188.3	.577
313.4	.474	453.5	.628	337.0	.649	212.3	.606
347.8	.495	523.0	.663	387.8	.687	236.9	.635
385.2	.517	578.5	.690	421.7	.710	267.4	.668
427.3	.541	700.0	.741	462.7	.738	294.9	.695
473.0	.563	.....	....	499.8	.760	328.2	.726
518.7	.587	.....	....	548.7	.788	378.6	.768
561.7	.605	.....	....	590.8	.807	414.5	.796
598.5	.620	.....	....	625.2	.825	449.6	.819
667.6	.648	.....	....	679.7	.850	517.5	.861
.....	....	.....	....	.....	....	554.4	.887
.....	....	.....	....	.....	....	640.8	.930
.....	....	.....	....	.....	....	677.6	.950

TABLE III

VALUES OF $\log_{10}$ ($10w$)

p in mms. of mercury	$d=4$ cms.	$d=4.27$ cms.	$d=4.5$ cms.	$d=4.65$ cms.	$d=4.8$ cms.	$d=5$ cms.	$d=5.3$ cms.	$d=5.5$ cms.
100	.158	.235	.312	.356	.418	.480	.567	.631
150	.279	.350	.426	.462	.522	.582	.654	.717
200	.356	.426	.498	.530	.584	.641	.719	.772
300	.456	.522	.585	.620	.667	.720	.793	.844
400	.522	.582	.642	.677	.722	.773	.843	.895
500	.569	.628	.685	.718	.761	.813	.881	.931
600	.605	.662	.718	.750	.793	.843	.910	.959

TABLE IV

d in cms.	$p=180$ mms. $k=.283$		$p=350$ mms. $k=.2535$		$p=550$ mms. $k=.237$	
	w from curves	w from formula	w from curves	w from formula	w from curves	w from formula
4.0	.213	.212	.312	.312	.387	.385
4.27	.250	.251	.358	.363	.442	.447
4.5	.296	.294	.412	.417	.504	.508
4.65	.321	.324	.448	.457	.545	.549
4.8	.364	.357	.497	.501	.602	.596
5.0	.417	.405	.562	.562	.675	.670
5.3	.498	.493	.662	.668	.788	.785
5.5	.567	.562	.745	.750	.882	.879

TABLE V

$d=5.16$ cms.

p in mms.	w from formula	w calculated from scale deflection	p in mms.	w from formula	w calculated from scale deflection
91.5	.316	.321	329.5	.597	.595
101.8	.332	.336	379.0	.634	.630
125.8	.378	.381	393.6	.649	.640
155.9	.422	.425	433.8	.668	.661
199.4	.475	.475	464.8	.688	.677
241.8	.519	.521	501.6	.708	.700
260.0	.535	.537	535.2	.726	.718
275.2	.549	.550	582.6	.746	.741
316.5	.586	.582	649.0	.774	.772

The values of w have been calculated by this method for p equal to 180, 350 and 550 mms. of mercury in the case of the diameters already dealt with and the calculated values of w are compared in Table IV with the corresponding readings of w obtained from the curves on chart 1. It will be noted that the error in most cases is less than one per cent. with two cases of two per cent. error and one case of three per cent. error.

A set of observations was also made for d equal to 5.16 centimetres for the purpose of further testing the formula. The values of w obtained from the formula 1 and from the scale deflections are given in the second and third columns respectively of Table V.

It would, therefore, appear that the depression of the centre of a disc under the arbitrary conditions laid down in the above experiments is characterized by a mathematical relation much simpler than the complicated nature of the differential equations of the theoretical development would lead one to expect. However, it should be borne in mind that the boundary conditions in the cases dealt with in these experiments differ from the conditions usually treated, for not only is the line of support during depression not at the edge of the disc but it assumes different distances from the edge of the disc for the various values of d.

The effect of the rim beyond the the exposed area of the disc must necessarily be considerable in these cases. It is intended at some future date to see what influence this rim has on the depression of the centre.

In conclusion I wish to express my thanks to Professor I. F. Morrison and Professor A. E. Cameron of the University of Alberta for tempering and preparing the steel disc for use in these experiments. Also I desire to express my appreciation of the courtesy shown me by the Associate Air Research Committee of Canada in permitting me to present this paper.

University of Alberta,
Edmonton.

The Vertical Movement of Alkali under Irrigation in Heavy Clay Soils

By FRANK T. SHUTT, D.SC., and ALICE H. ATACK, B.A.

(Read May 18th, 1922)

Irrigation has made possible the successful, profitable cultivation of large areas hitherto unproductive owing to a scanty rainfall. In arid and semi-arid districts irrigation has reclaimed and rendered fertile hundreds of thousands of acres otherwise barren and unprofitable for agriculture. But it is a practice which to be safely applied demands a full knowledge of soil conditions—the alkali content of the soil—the texture of the soil and drainage facilities. Thus it is that in the work of classification many factors must be studied, many problems solved before a safe decision can be reached with respect to the wisdom of placing any particular area under irrigation.

Many of these problems are concerned with the presence of "alkali," the accumulation of certain soluble salts in the soil, characteristic of many arid and semi-arid tracts. This alkali may vary in composition and in concentration, as well as in position. It differs also in toxicity to vegetation.

In the examination of the soils of the semi-dry belt of the Western Prairie provinces, alkali impregnation, though somewhat widely distributed, has not condemned any large irrigation projects as non-irrigable, but there are areas here and there of greater or less magnitude which have been "cut out" on the grounds that irrigation sooner or later would in all possibility result in "rise of alkali" and destroy the land for farming purposes. In the course of the work many doubtful cases occur, rendering it extremely difficult to reach a conclusion; the classification must be safe, if conservative, but the benefits of irrigation are so great that no land should be classed as non-irrigable without unmistakeable evidence that injury would follow the application of water.

A typical problem of this character is that of a rather extensive tract of land at Tilley. (Sec. 24, Tp. 17, Rge. 13, West 4th Meridian) Alberta. The conditions here are a surface soil of heavy, impervious clay loam of good quality and free from all save traces of saline matter, but very difficult to work and drain. This overlies a subsoil of extremely heavy impervious clay carrying a serious impregnation of alkali. In 1915 it was decided that several years investigations of the movement of alkali under irrigation in a soil of this quality would be very advantageous in furnishing reliable information upon which to base recommendations for further projects of this character. Accordingly two plots were chosen about 50 feet apart upon the C.P.R. Demonstration Farm at Tilley from which two groups of samples were collected and analysed, each group consisting of four members representative of the following depths: "A" 0′.0−0′.5; "B" 0′.5−1′.5; "C" 1′.5−3′.0; "D" 3′.0−5′.0. Similar groups from these plots have been taken and examined annually since that date.

The Transactions of the Royal Society of Canada for 1921 contain a report of the first five years' investigations. The present paper records the results of last year's investigations, (1921) and in order more closely to correlate the physical and chemical properties the results of a complete mechanical analysis of these two groups of soil have been incorporated.

Irrigation water was applied for the first time in 1915. Hence the following results of analyses indicate the position and nature of the saline content to a depth of 5 feet during the seven seasons of the investigation. The water applied has been approximately 1½ acre feet annually.

The mechanical composition of this soil is fairly uniform to the depth sampled. The soil consists chiefly of silt and clay in almost equal amounts, the proportion of coarser soil particles present is very small, consequently the soil is stiff and highly impervious and it is to be expected that soil water would move very slowly through it. Evaporation at the surface, it might be argued, would have but little effect upon the upward movement of the moisture of the subsoil of this type compared with its effect upon a subsoil of a more porous character, and it might be found that judicious irrigation, accompanied by efficient surface drainage could be safely practised, even though the subsoil is heavily impregnated with alkali. Fortunately for the future of this area the results of analysis of the water-soluble content of the soil made each successive year have shown that the irrigation water has not materially affected the location of the alkali. On comparing the different columns of Table I. and more particularly the results for Group No. 1585 A and B and 1747 A and B—it will be evident that practically no change has taken place in the nature or position of the small quantities of saline matter present. At the end of seven years, irrigation has lowered rather than raised the saline matter of the chief root feeding zone—the first foot and a half of soil.

Plot I.—Water-soluble Saline Content Expressed in Percentages on Air-Dried Soil.

Crops.—1916, Wheat: 1917 and 1918, Western Rye Grass, Timothy and Brome: 1919, White Clover: 1920, Mixed Grasses and Clover: 1921, Mixed Grasses and Clover.

TABLE I.

Group No.		Total Solids after Ignition	CaO	MgO	Na_2O	SO_3	CO_2
1209	A	.200	.034	.001	.107	.058	.032
(1916)	B	.520	.052	.051	.162	.235	.048
	C	4.840	1.156	.387	.454	2.855	.030
	D	4.048	.942	.266	.453	2.301	.028
1611	A	.160	.020	....	.079	.016	.044
(1917)	B	.160	.022	....	.104	.027	.074
	C	4.672	1.393	.220	.358	2.655	.042
	D	2.400	.501	.159	.350	1.399	.037
1652	A	.200	.040	.023	.070	.033	.044
(1918)	B	.184	.060	.029	.068	.028	.065
	C	.300	.069	.036	.087	.092	.039
	D	1.736	.365	.100	.235	.972	.035
1678	A	.146	.071	.013	.072	.060	.028
(1919)	B	.270	.037	.013	.118	.117	.047
	C	.902	.151	.068	.214	.548	.033
	D	2.036	.384	.141	.340	1.282	.035
1585	A	.130	.013	....	.053	.027	.047
(1920)	B	.176	.028	....	.056	.015	.044
	C	2.800	.728	.197	.276	1.448	.035
	D	4.052	.708	.403	.576	2.127	.032
1747	A	.204	.055	.010	.072	.020	.025
(1921)	B	.150	.049	.010	.050	.020	.024
	C	3.742	1.133	.233	.289	2.386	.012
	D	2.004	.443	.141	.295	.959	.007

With respect to the zones "C" and "D", the results from year to year are rather erratic showing remarkable fluctuations. It is doubtful whether these movements can be attributed wholly or in part to irrigation, for field notes made on examinations following an irrigation indicate that the water had not penetrated below 1′.5. A rise or fall of the water-table would, of course, be accompanied by a corresponding change in the position of the alkali, but over this area the water-table lies at a very great depth. The probable explanation is that the alkali at depths lower than 1′ 6″ has not been

Plot I—Mechanical Composition Expressed in Percentages on Air-Dried Soil

TABLE II.

Size Particle	Diam. in mm.	A	B	C	D
Fine gravel..........	2–1	.03	.57	.22	.40
Coarse sand.........	1– .5	1.81	2.98	2.30	1.41
Medium sand........	.5–.25	1.77	1.83	2.28	3.46
Fine sand...........	.25–.1	3.35	2.22	3.00	12.15
Very fine sand.......	.1–.05	19.96	13.95	7.20	20.99
Silt................	.05–.005	41.25	46.60	50.29	34.33
Clay...............	<.005	31.08	30.95	34.57	26.74

affected by the irrigation or soil water and the irregularities in alkali content as noted from year to year are due to uneven alkali depositions (as has been proven in many instances) and the fact that successive collections are made at points some few feet distant from one another. The important fact to be noted is that at no time during the course of the experiment has the alkali risen to the root-feeding zone.

Plot II.—There is very little difference in the mechanical composition of soils from the two plots. That, from Plot I. contains a small proportion of coarse particles, while that from Plot II. contains practically none, but the proportions of fine sand, very fine sand, silt and clay are almost identical. Consequently, since the same conditions in regard to alkali prevail, the investigations upon one plot should serve as a check upon those of the other although a slight difference should be expected due to the fact that Plot I. is 40′ south and 50′ west of the head ditch and lateral, while Plot II. is only 10′ south and 10′ west. After seven years' irrigation the upper 18 inches of this plot also are practically free from saline matter, while, as in Plot I., very erratic results for the alkali in the subsoil are to be observed. No doubt the cause of these irregularities is the same for both plots.

Field note records state that for seven years each plot received three irrigations every season, and that at no time during the whole seven years' irrigation has there been any surface indications of alkali. After this year's investigations we may repeat with greater confidence a statement of conclusions in last year's report: "Irrigation under the conditions of the experiment has not caused any appreciable rise of alkali." Notwithstanding a close, almost impervious subsoil, strongly impregnated with alkali, it would seem possible

Plot II.—Water soluble Saline Content Expressed in Percentages on Air-Dried Soil.

Crops.—1916, Clover: 1917, Alfalfa: 1918, Wheat and Alfalfa: 1919, Pasture: 1920, Barley, Clover and Alfalfa: 1921, Volunteer Barley.

TABLE III.

Group No.		Total Solids after Ignition	CaO	MgO	Na_2O	SO_3	CO_3
1210	A	.160	.031	.014	.087	.033	.039
	B	.152	.034	.013	.087	.023	.053
(1916)	C	3.420	.811	.222	.326	1.916	.032
	D	3.676	.918	.252	.423	2.060	.032
1612	A	.300	.049	.025	.095	.119	.065
	B	2.140	.492	.167	.191	1.243	.037
(1917)	C	2.984	.643	.232	.390	1.696	.030
	D	2.920	.665	.217	.358	1.683	.030
1651	A	.152	.025	.015	.082	.025	.039
	B	.208	.031	.032	.103	.026	.079
(1918)	C	4.668	1.277	.391	.349	2.562	.039
	D	2.072	.374	.177	.349	1.168	.026
1679	A	.166	.061	.017	.058	.054	.032
(1919)	B	.140	.042	.038	.053	.044	.044
	C	.904	.305	.058	.089	.519	.034
	D	3.206	1.049	.145	.182	1.837	.032
1586	A	.184	.031	.018	.096	.029	.029
(1920)	B	.208	.100	.018	.109	.072	.053
	C	4.038	1.411	.137	.226	2.289	.029
	D	1.944	.462	.137	.337	1.036	.025
1746	A	.190	.043	.015	.080	.020	.018
(1921)	B	.218	.022	.015	.080	.030	.023
	C	4.476	1.468	.123	.135	2.294	.016
	D	2.040	.487	.140	.144	1.069	.009

that an area of heavy clay may be safely irrigated for a number of years, provided that the irrigation be judicious, say, approximately 1½ feet annually and that at the outset the surface soil to a depth of 1′ 6″ is free from alkali, and further, that provision is made for the removal of surplus water by surface drains and ditches.

Note.—Mechanical analyses of soils from both plots were made by Mr. John M. Macoun.

Plot II.—Mechanical Composition Expressed in Percentages on Air-Dried Soil.

TABLE IV.

Size of Particle	Diam. in mm.	A	B	C	D
Fine gravel..........	2. − 1.	.15	....	....	.12
Coarse sand.........	1. − .5	.55	.16	.48	.77
Medium sand.......	.5 − .25	.76	.38	1.38	1.54
Fine sand...........	.25 − .1	3.78	3.37	4.90	6.31
Very fine sand.......	.1 − .0	19.53	18.92	10.81	11.83
Silt................	.05 − .005	37.14	42.09	44.20	40.12
Clay...............	< .005	38.06	34.89	38.19	39.20

The "Alkali" Content of Soils as Related to Crop Growth

By FRANK T. SHUTT, M.A., D.SC. and ALICE H. ATACK, B.A.

(Read May 18th, 1922)

The reclassification of certain areas within the semi-dry belt of Southern Alberta into irrigable and non-irrigable lands has been in progress for the past nine years. This work is under the direction and control of the Reclamation Service (formerly the Irrigation Branch) of the Department of the Interior, but the chemical and physical examination of the soil necessary to arrive at a decision as to the probability of "rise of alkali" following irrigation and the general suitability of the land for cultivation under irrigation, a very important phase of the work, has from the first been undertaken by the Division of Chemistry of the Dominion Experimental Farms System.

This chemical work has involved the analysis of many hundreds of groups of soil and the data thus amassed respecting the nature, concentration and disposition of soil "alkali" have already proven of immense value in the safe classification of very large tracts of lands. No tract or area has been "passed" as irrigable which indicated from the chemical or physical results that there was the probability of a rise of alkali and injury to the land from the application of water.

Naturally, in the course of this work many problems have arisen demanding special investigation and one of the most important and urgent of these has been the relation of alkali—its character, concentration and disposition in the soil—to crop growth; in other words the determination of the limits of toxicity to ordinary farm crops.

This investigation has been under progress since 1918, and three reports have already been made to The Royal Society (1918, 1919, 1920) upon the subject. In these papers the nature of the problem, the character of the alkali found and the urgent necessity for reliable data have been explained in detail. The present paper contains additional information upon the same subject and attempts to correlate and interpret the results of this and previous years' work.

Series of samples have been taken and field notes made upon the quality of the soil, condition of the crop and general methods of cultivation by the Field Engineer; these samples with the accompanying particulars were then forwarded to Ottawa for analysis. Each series consists of three groups taken from the same field, representing land upon which (1) the growth of the crop was good, (2) the growth was poor and beginning to show signs of distress from alkali and (3) upon which there was no growth due to excess of alkali. Accordingly, these groups represent soil essentially free from alkali, soil in which the alkali content is sufficient to have a certain toxic effect upon the crop in question and soil so seriously impregnated with alkali as to prohibit all growth. Each group consists of four samples, "A" represents a depth of 0′.0–0′.5, "B" 0′.5–1′.5, "C" 1′.5–3′.0, "D" 3′.–5′.0. The previous papers submitted in this investigation record the results of the examinaton of thirteen series of soil groups, the crops involved were Western Rye Grass, Native Prairie Grass, Oats, Wheat, Onions, Timothy, Vetch and Rye. The present report upon soils collected in 1921 deals with areas sown to wheat.

Wheat

Series XIV. Sec. 26, Tp. 18, R. 14, W. of the 4th Meridian.

This series of samples was taken in August, 1921 from a field of wheat, which had been irrigated early in June. The water had evidently not penetrated farther than 1′.5. The growth on the field was rather irregular, good healthy wheat on the whole, but some patches showed signs of distress from alkali, and the bare spot from which Group 1752 was taken stretched 200′ N.E. and S.W. and measured about 20′ wide. The spot was very moist but no incrustations of alkali appeared on the surface.

It is probable that the toxic effects apparent in this field are due to both sodium sulphate and sodium carbonate. Chlorides are absent throughout the series. In "D" of Group 1754 there is a trace of magnesium sulphate, while both Groups 1754 and 1753 below 3′.0 contain a considerable amount of calcium sulphate.

Group 1754.—Good even growth of healthy wheat on an even gentle slope. The location of group was about 539′ west of the bare spot or patch (Group 1752) which, however, shows no surface indication of alkali.

Nature of Soil.—"A" dry chocolate-grey, heavy silt loam, well supplied with organic material; "B" dry, dark yellow-grey light clay loam; "C" fine dry, grey-white silt; "D" essentially same as "C."

Wheat

Sec. 26, Tp. 18, R. 14, W. of the 4th Meridan. Collected August 25th, 1921.

Group	Depth	Growth	Na_2SO_4	$CaSO_4$	$MgSO_4$	Na_2CO_3	Total Soluble Saline Content
1754	0'.0–0'.5	Good	.036	.....	....	.028	.166
	0'.5–1'.5		.036	.....	....	.069	.176
	1'.5–3'.0		.084	.....	....	.079	.218
	3'.0–5'.0		.515	1.224	.174	....	1.888
1753	"	Poor	.036	.....	....	.072	.240
			.255	.....	....	.108	.444
			1.244	3.369	....	....	4.736
			1.377	.....	....	.114	1.536
1752	"	None	.975	.....	....	.073	1.116
			.682	.....	....	.252	1.036
			.968	.....	....	.238	1.332
			1.022	.....	....	.211	1.408

To a depth of 3' this soil is free from all save traces of saline matter. "D" contains appreciable amounts of sodium, calcium and magnesium sulphate, but this is apparently so far below the active root zone that the crop is not affected.

Group 1753.—Distressed and meagre growth of wheat: ground level and fairly even, sample collected 30' west of the bare spot (Group 1752) and 500' east of Group 1754. Nature of soil: dry, chocolate-coloured light clay loam, well supplied with organic material "B" dry, slate-grey light clay loam; "C" moist, dark yellow-grey fine silt, lighter in colour than C.

In the surface 6" of this soil the amount of sodium sulphate is practically negligible; in "B," however, it amounts to .25 per cent. and increases to more than 1 per cent in "C" and "D". The distressed appearance of the crop is probably due mostly to the sodium carbonate present—.07 per cent. in "A" and .1 per cent. in "B"—an amount evidently close to the toxic limit for wheat.

Group 1752.—Taken from a bare patch of irregular outline, about 200' long and 20' wide, most of the patch being absolutely bare and very moist half an inch below the surface. Nature of the soil: "A" moist, grey, light clay loam, tilth rather poor.; "B" moist, slate-grey, light clay loam with yellow streaks; "C" damp, light yellow-grey, fine silt; "D" very similar to "C" but lighter in colour.

The percentages of sodium sulphate and sodium carbonate in the root zone are evidently well beyond the limit of safety. While in some cases it has been found that .975 per cent sodium sulphate is not sufficient to completely prevent growth, this accompanied by appreciable amounts of sodium carbonate as in this instance has always proved inhibitive to vegetative growth.

Wheat

SERIES XV. Sec. 35, Tp. 18, R. 14, W. of the 4th Meridian.

This series of samples was taken in August, 1921 from an irrigated wheat field in the Duke of Sutherland's property—the last application of water having been made on the 25th of June. Generally viewed the field bore a healthy stand of wheat but seepage from the canal was beginning to cause distress in spots.

Wheat

Sec. 35. Tp. 18, Rge. 14, W. of the 4th Meridian. (Irrigated).

Collected August 18th, 1921.

Group	Depth	Growth	Na_2SO_4	$CaSO_4$	$MgSO_4$	Na_2CO_3	Total Soluble Saline Content
1751	0′.0–0′.5	Good	.028	.....	....	.041	.122
	0′.5–1′.5		.018	.....	....	.036	.100
	1′.5–3′.0		.320	.....	....	.082	.414
	3′.0–5′.0′		1.230	.317	.129	....	1.708
1750	"	Good	.045	.....	....	.026	.144
		but	.036	.....	....	.029	.132
		stem	.225	.....	....	.086	.336
		coloured	1.230	.288	.067	....	1.664
1749	"	Poor	.045	.....	....	.065	.184
			1.110	.187	.042	....	1.360
			1.706	.314	.042	....	2.322
			2.224	1.591	.048	....	4.212
1748	"	None	2.599	.737	.687	....	4.538
			1.340	.341	.060	....	1.910
			1.168	.207	....	....	1.508
			1.403	.479	....	....	2.002

Group 1751.—These samples were taken from an even level slope bearing a healthy stand of wheat. Nature of Soil: "A" moist, light chocolate, heavy silt loam, well supplied with organic matter; "B" moist, dark slate-grey, light clay loam; "C" moist, yellow-grey, coarse to fine silt; "D" moist, yellow-grey, fine silt.

Judging from the appearance of the crop the percentage of saline matter present in the upper 3′ is negligible; "B" contains rather more than a trace of sodium carbonate, "C" an appreciable amount and "D" contains more than 1 per cent. sodium sulphate, which evidently at such a depth has no effect upon the vigour of the crop.

Group 1750.—This group was taken from a slope where the stand of wheat was as luxuriant as could be desired but the lower part of the stems showed a peculiar purple colour. Nature of soil: "A" moist, dark chocolate, heavy silt loam with a good supply of organic material; "B" moist, chocolate light clay loam; "C" moist yellow-grey fine silt; "D" essentially the same as "C".

The alkali content of this soil is practically the same as that of Group 1751, containing only a little less sodium carbonate in "A" and "B". The engineer collected this sample on account of the peculiar discolouration of the wheat stem. This is the first time that this abnormal appearance in wheat has been noticed and the results do not indicate that it is a symptom of alkali trouble.

Group 1749. The crop at the point from which this sample was taken was poor and distressed, showing signs of marked injury from alkali. Nature of soil: "A" moist, yellow to slate-grey, heavy silt loam, fairly well supplied with organic material; "B" moist, slate-grey, light clay loam; "C" moist, slate-grey, coarse to fine silt; "D" essentially the same as "C."

The results here correspond very closely with the analyses of Group 1753. The toxic effect is evidently due to the sodium sulphate and sodium carbonate present; magnesium sulphate is only in negligible amounts, and while 1749B contains more sodium sulphate than 1753B there is no doubt that the .06 per cent. sodium carbonate in 1749B is chiefly responsible for the distressed appearance of the crop.

Group 1748—At this point all growth had ceased. The group was taken from an absolutely bare spot showing alkali incrustations. Nature of soil: "A" damp, chocolate coloured, heavy silt loam; "B" damp, yellow-grey, coarse silt; "C" wet, yellow-grey, coarse silt; "D" essentially the same as "C."

The absence of all growth here clearly proves that the limit of endurance for wheat has been passed. This toxic effect is due chiefly to the large amounts of sodium sulphate present, although it is probable that the .687 per cent. magnesium sulphate is to some degree an additional injurious factor.

It is desirable that more work should be done upon this problem before the limits of tolerance are fixed definitely and finally. Further evidence confirming results obtained with respect to the alkali tolerance of the crops already investigated must be obtained but it seems justifiable, however, at this point to sum up the work accomplished to date and tentatively to adopt limits of tolerance for the crops examined. In this we have regarded an area of distressed growth as representing soil impregnated with an amount of alkali approaching the limits of safety for the crop in question and the following data from such areas, extracted from results published in former papers, have been tabulated with a view to presenting the evidence to date.

Wheat—Distressed Growth

Group No.	Na_2SO_4	Na_2CO_3	°Group No.	Na_2SO_4	Na_2CO_3
1663 A	.123	....	1687 A	.505	.078
B	.701	....	B	.591	.111
1661 A	.231	....	1753 A	.036	.072
B	.113	....	B	.255	.108
1664 A	.457	....	1749 A	.045	.065
B	.740	....	B	1.110	....

It seems apparent from a study of the above table that for wheat the limit of sodium sulphate in the chief root feeding zone (0′.0–1′.5) is between .5 and 1.0 per cent., for sodium carbonate from .06 to .07 per cent. It is not evident why the "limit" in Group 1661 appears so much lower and in all probability its sickly crop was in part due to some cause other than alkali.

Western Rye Grass—Distressed Growth

Group No.	Na_2SO_4	Na_2CO_3
1602 A	.117	....
B	.254	....
1658 A	.227	....
B	.038	....

Western Rye grass seems to be a comparatively non-resistant crop; .2 per cent sodium sulphate is apparently the toxic limit.

It has generally been held that this grass is strongly resistant to alkali but the evidence to date does not confirm that view.

Native Prairie Grass—Distressed Growth

Group No.	Na_2SO_4	Na_2CO_3
1605 A	.432	....
B	1.001	....

Native Prairie Grass is, very probably, rather more resistant than wheat, the toxic limit of sodium sulphate is not reached until there is 1.0 per cent. in the root feeding zone.

Oats—Distressed Growth

Group No.	Na_2SO_4	Na_2CO_3
1619 A	.108	.212
B	....	.149
1667 A	....	.243
B	....	.100
1692 A	.912	....
B	1.054	....

The limit of sodium sulphate for oats appears to be about .9 – 1.0 per cent; of sodium carbonate approximately .2 per cent.

Onions—Distressed Growth

Group No.	Na_2SO_4	Na_2CO_3
1627 A	....	.224
B	....	.120

The limit of sodium carbonate for onions is evidently about .2 per cent.

Timothy—Distressed Growth

Group No.	Na_2SO_4	Na_2CO_3
1695 A	.753	....
B	.215	....

Apparently Timothy is slightly less resistant than wheat, the limit of tolerance toward sodium sulphate is about .7 per cent. in the root feeding zone.

Vetch and Rye—Distressed Growth

Group No.	Na_2SO_4	Na_2CO_3
1700 A	.208	.253
B	.073	.127

The toxic factor here is no doubt the sodium carbonate—probably .2 per cent would represent the limit of sodium carbonate for Vetch and Rye. Further investigation is necessary to supply evidence for a limit of sodium sulphate.

Of all the series examined magnesium sulphate seemed to occur only in places where sodium sulphate had already reached and exceeded a toxic amount, so that from data accumulated it is impossible to draw any inferences about the toxic quality of magnesium sulphate other than that it adds to the general injurious effect of sodium sulphate and sodium carbonate.

On Photo-electric Conductivity of Diamond and Other Fluorescent Crystals

By MISS M. LEVI, B.A.

(Read May Meeting, 1922)

1. INTRODUCTION.

A number of substances have been discovered which, like selenium, exhibit the phenomenon of photo-electric conductivity,—that is, their electrical resistance undergoes a change on exposure to radiation. In most cases the resistance is decreased on illumination, when the effect is said to be photo-positive. In some cases, however, it has been found that under certain conditions of applied voltage and wave-length of exciting light, the resistance is increased. The latter effect is said to be photo-negative. In no case has a substance been found whose resistance is always increased when light falls on it.

Among the substances which show the effect are minerals like molybdenite, stibnite and silver sulphide, which are to a greater or less extent conductors of electricity, and others such as zinc sulphide, cinnabar and diamond, which are known as insulators, but which, nevertheless, become conducting under the influence of light.

In view of the fact that a number of fluorescent materials are photo-sensitive, it was thought to be of interest to investigate the photo-electric properties of some fluorescent crystals. Six diamonds and a few samples of fluorescent kunzite and willemite were chosen for investigation.

2. APPARATUS AND METHOD.

It was first desired to obtain the relation between the photo-electric current per unit of exciting light energy, and the wave length of exciting light. For this purpose the following apparatus was used.

The source of radiation was a mercury arc lamp in quartz, of the Heræus type, which was run at a steady current of 2 amperes. The lamp was mounted in front of the slit of a Hilger constant deviation spectrometer, fitted with quartz prism and fluorite lenses, so that radiation far down in the ultra-violet could be used. For work with the continuous spectrum, a powerful self-regulating carbon arc was employed.

The crystal was securely mounted in a holder between two flat electrodes faced with tin foil. Small springs kept the electrodes pressed against the crystal, thus insuring good contact. The holder was fixed at the exit slit of the spectrometer, whose calibrated drum enabled any desired wave-length of light to be focussed on the crystal. The light fell on the crystal with perpendicular incidence, and when not desired could be cut off by a shutter.

A set of storage batteries allowed fields up to 11,500 volts per cm. to be applied to the crystal.

To measure the photo-electric current, a sensitive Broca iron-clad galvanometer was used. Its senitivity was 2×10^{-9} amps. per mm. deflection with scale distance of 1 meter, and its period was 26 seconds. To protect the galvanometer, a water resistance was kept in series with it.

The energy in the radiation from the lines of the spectrum was measured by a sensitive bismuth-silver thermopile, placed at the exit slit of the spectrometer. Measurements of the thermo-electric current were made with the same galvanometer, which was sensitive enough to register the effect of radiation as far down as $\lambda = 2400$ A. Although great care was taken to keep the current through the lamp steady, it was found that energy measurements varied considerably. For that reason, energy measurements were repeated before each set of readings for photo-electric effect, and the final values used were the averages of four readings.

The arrangement of the apparatus is shown in Fig. 6.

3. Properties of the Crystals.

(*a*) *Description.*

1. Diamond No. 1 was in the shape of an approximately rectangular plate, about 7 mms. by 5 mms., the thickness varying from .75 mms. at one end to 1.5 mms. at the other. One of the large faces was quite plane, the difference in thickness being occasioned by a curvature on the other large face. It was a natural crystal, quite colourless and semi-transparent.

2. Diamond No. 2 was an irregularly shaped plate, roughly 6 by 4 by 1 mms. It was formed by the growth together of two crystals, and contained a large, black occlusion. It also was a natural crystal, whose colour was not as clear as that of diamond No. 1.

3 Diamond No. 3 was an oval plate, 11 by 9 by $1\frac{1}{2}$ mms., beautifully cut and polished. It was quite colourless and transparent.

4. Diamond No. 4 was triangular in shape, of side 8 mms. and of 1 mm. thickness. It was distinctly coloured, with a brownish tinge, and was a transparent, natural crystal.

5. Diamond No. 5 was a very clear, natural crystal, about 6 by 4 by 1 mms. with a triangular etch figure on one of its faces.

6. Diamond No. 6, about 5 by 5 by 1 mms., was a natural crystal, nearly opaque, with a surface of granular appearance.

7. Small crystals of willemite for examination were broken off from a large sample which came from Franklin, New Jersey. The mineral was of a pale green colour and quite opaque.

8. The crystals of kunzite used were loaned to Prof. McLennan through the kindness of Dr. Kuntz, of Messrs. Tiffany, New York. The mineral was of a pale purple colour and semi-transparent.

(*b*) *Spectral Absorption.*

The photographs shown in Plate 1, Fig. 1 were obtained with a quartz spectrograph, using a mercury arc in quartz as a source of light and interposing each crystal in succession between the source of light and the slit of the spectrograph. It is seen that diamonds Nos. 3, 4, and 5, although more transparent in the visible, were opaque to radiation in the ultra-violet of shorter wave-length than $\lambda = 2967$ A, while diamonds No. 1 and No. 2 were the only crystals transparent down to $\lambda = 2000$ A.

Thermopile measurements of the energy from the carbon arc were made with diamond No. 1 interposed between the source of light and the slit of the spectrograph. By comparing these with measurements made when the diamond was removed, data for the curve in Fig. 1 were obtained. From this curve, in which per cent. absorption was plotted against wave-length, it is seen that diamond No. 1 showed rapidly falling absorption with decreasing wave-length.

(*c*) *Fluorescence and Phosphorescence.*

The fluorescing and phosphorescing properties of the crystals were observed under the influence of gamma rays. It was found that all the diamonds showed a bluish luminosity, the cut edges of diamond No. 3 being particularly bright. It was also noticed that willemite glowed a bright green and kunzite a dull red under the gamma rays. On removing the source of radiation, the luminosity of all the crystals vanished, except that of diamond No. 1, which continued to glow for many minutes. These characteristics are illustrated in the photographs in Plate 1, Fig. 2.

A photograph of the fluorescing crystals was obtained by placing them on the sensitive side of a plate and subjecting them to the influence of gamma rays for one hour. The fluorescence is shown in the bright lines around the edges of the crystals. After removing the source of exciting rays, the crystals were placed on another photographic plate, but the only impression then made was that of diamond No. 1, the only crystal which was phosphorescent.

(*d*) *Photo-electric Conductivity.*

Upon preliminary examination with heterochromatic light, it was found that of the six diamonds, only samples No. 1 and No. 2 showed a change in conductivity when exposed to illumination. With the other diamonds, no appreciable currents were registered in the most intense available light and in fields as high as 11,500 volts per cm.

4. Photo-electric Properties of Diamonds.

(*a*) *Conductivity of Unilluminated Diamond No. 1.*

On applying a field to the unilluminated crystal, a small current was observed. When the direction of the field was reversed, this current was absent, showing that the crystal was conducting in one direction. On illumination, a photo-electric current resulted irrespective of the direction of the external field, but of much greater magnitude in the direction in which the "dark" current flowed. This property of unidirectional conductivity has been observed in other light sensitive substances, and its connection with the photo-electric phenomenon will be discussed later.

(*b*) *Effect of Time of Exposure on Photo-electric Current.*

On illuminating the crystal, it was found that the photo-electric current (measured by subtracting from the total galvanometer deflection that due to the dark current) increased with time, rising slowly to a maximum. The lag of photo-electric response varied considerably with wave-length of exciting light, and the time for complete recovery was always longer than that of exposure.

Time-current curves shown in Fig. 2 are typical. In taking observations the light was shut off when the galvanometer deflection reached its first maximum. Equilibrium conditions could not be obtained, for with passage of time came irregularities in the motion of the image on the scale which reached such magnitudes as to make readings impossible. The broken curve in Fig. 2 is typical of the behaviour of the current after a long time of exposure to light.

This instability, which appears with time and with high voltage, corresponds to the component of the photo-electric current named by Gudden and Pohl[1] the secondary current. It occurs irrespective of the direction of the current through the crystal, and its appearance substantiates the hypothesis of Gudden and Pohl that conduction takes place by means of negative carriers which, becoming separated from netural atoms, leave them positively charged. The positive ions then create a space charge within the crystal, with consequent establishment of strong counter fields. The latter may become strong enough to overbalance the external field, in which case the current in the crystal will flow in a direction opposite to that due to the external field. Upon the demolishing of the counter fields with the passage of this current, the influence of the external field becomes predominant. Such a hypothesis would account for the surging back and forth of the current, which was observed after lengthy exposure of the crystal to light, in a strong field.

(*e*) *Effect of Wave-length of Exciting Light.*

These irregularities made it necessary to exercise care in taking readings of photo-electric currents at various wave-lengths. To obtain uniformity, the crystal was illuminated for exactly 15 seconds for every reading, and the maximum deflection attained in that time was taken as the value of the photo-electric current. After shutting off the light, the applied potential was removed for several minutes, so as to bring the crystal back to its original state for every reading. With these precautions, steady and consistent results were obtained.

The curve in Fig. 3 is an example of the results obtained. The abscissæ represent wave-length in Ångstrom Units, and the ordinates photo-electric current per unit of light energy per second. From the figure, it is seen that diamond No. 1 is increasingly sensitive with decreasing wave-length, the maximum sensitivity being at $\lambda = 2536$ A. By comparison with the work of Gudden and Pohl[2] it may be concluded, from the deviation from a smooth curve in Fig. 3, that diamond No. 1 contains impurities.

Repeated measurements gave the same characteristic curve, regardless of the direction of the external field and the magnitude of the applied voltage. Variation of these conditions changed the value of the photo-electric current, and hence of the ordinates in Fig. 3, without affecting the character of the curve.

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[1]Gudden and Pohl, Zeitschr. fur Physik, 6, p. 249; also 7, p. 65, 1921.

[2]Gudden and Pohl, Zeitschr. fur Physik, 3, p. 125, 1920.

Photo-electric Properties of Diamond No. 2.

Diamond No. 2 differed from Diamond No. 1 in that it showed a high photo-electric sensitivity in fields as small as 40 volts per cm. Like diamond No. 1, the unilluminated crystal was conducting in one direction only, and comparatively large currents could be obtained through it on the application of very small potentials.

Readings of the photo-electric sensitivity were made in a field of 80 volts per cm. At this voltage the dark current was so large that the image moved off the scale, but a fairly steady zero was maintained by means of a bar magnet, adjusted so as to keep the spot of light at the desired position on the scale. The difficulty mentioned in connection with diamond No. 1, of great unsteadiness in the photo-electric current, was not encountered with the potential used, but became serious as the voltage increased.

Fig. 4 gives a number of curves showing the rise and decay of photo-electric current with time. It is of interest to note that the current continued to flow a short time after the light was shut off, when the time of exposure to light was not sufficient for the current to reach a maximum. As in crystal No. 1, the lag in decay of the current was considerably greater than the lag in growth.

Fig. 5 shows the variation of photo-electric sensitivity of diamond No. 2 with wave-length of exciting light. It is very similar to that obtained for diamond No. 1. The deviation from a smooth curve is present, and the rise in sensitivity in ultra-violet light is also evident. The maximum sensitivity occurs at $\lambda = 2894$ A.

Properties of Kunzite and Willemite.

Crystals of kunzite and willemite were absolutely non-conducting when unilluminated. On exposure to light they showed no trace of being photo-sensitive either at room temperature or when cooled to $-15°C$.

Undirectional Conductivity.

As has been mentioned, diamonds No. 1 and No. 2 showed unidirectional conductivity. On investigation, it was found that the magnitude of the current obtained through the unilluminated crystal was governed by the direction of the current through the crystal. This result is illustrated in the diagrams in Fig. 6. For this work, diamond No. 1 was used. The change in direction of the current between positions I and II was made by means of a reversing switch.

From these figures, it is seen that the dark current flowed only when the direction of the current in the crystal was from face B to

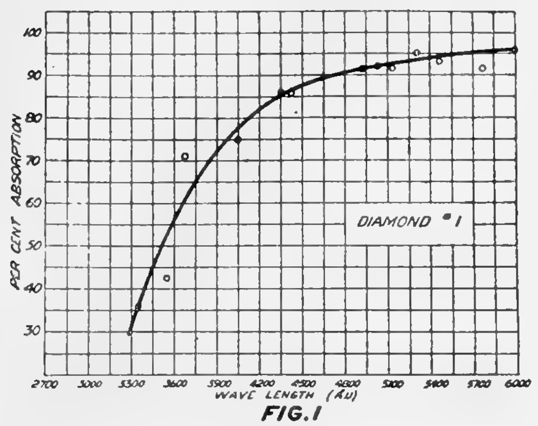

FIG. 1

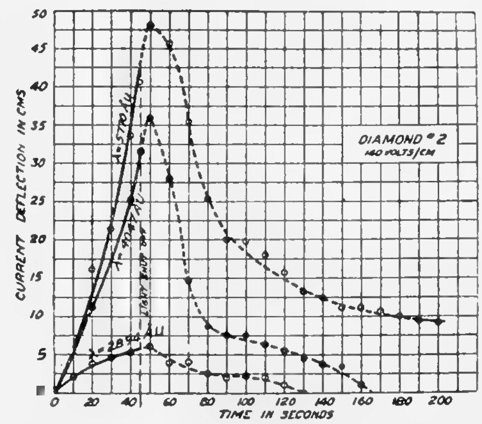

FIG. 4

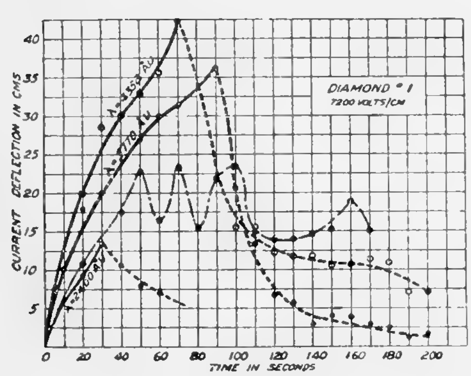

FIG. 2

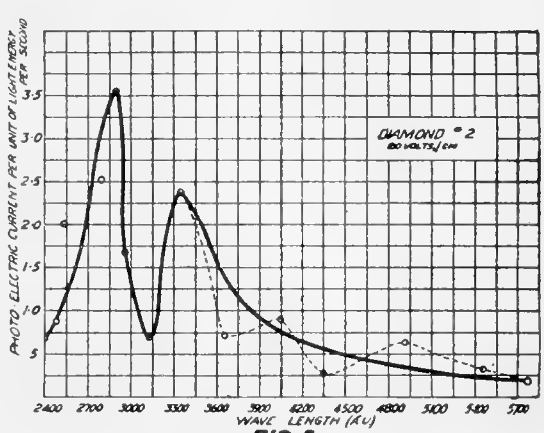

FIG. 5

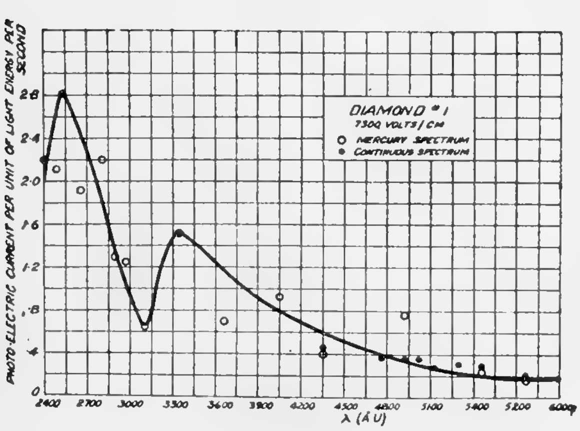

FIG. 3

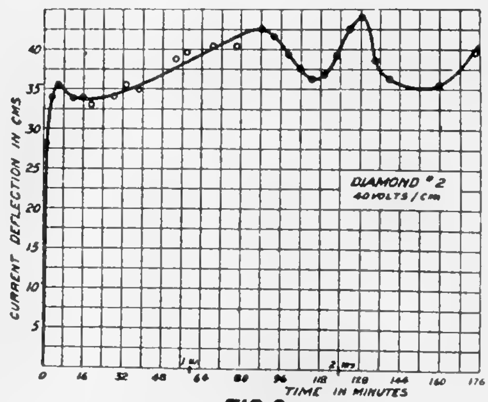

FIG. 8

face A, no matter which terminal of the battery was earthed. Repeated tests confirmed this conclusion. The same characteristic held for diamond No. 2.

The dark current became greater with time of application of the field, and on higher voltages there was also a small current from face A to face B. The growth of current with time in diamond No. 1 is illustrated in Fig. 7, which shows no saturation, but continues to grow. Fig. 8 illustrates the growth of current with time in diamond No. 2, and shows that the current reached a saturated state. This curve also shows that the current was unstable, and did not reach a state of equilibrium.

The variation of dark current with voltage is seen in Fig. 9 for diamond No. 1, and Fig. 10 for diamond No. 2. For these curves, deflection attained in 10 seconds was taken as a measure of the dark current. The numbers on the curves in Fig. 9 refer to the positions illustrated in Fig. 6. The law established by Streintz and Wessely[3]

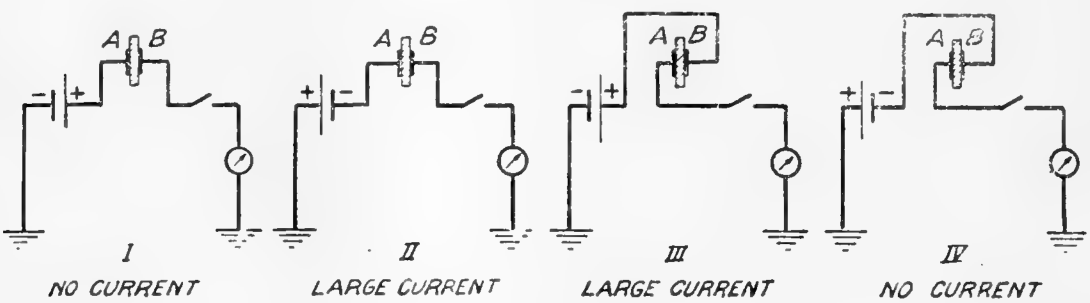

Fig. 6

for lead glance and iron pyrites crystals, that the unipolarity U, defined as $U = \frac{I_{12} - I_{21}}{I_{21}}$, is proportional to applied voltage, did not hold for the diamonds. In the above formula, I_{12} is the current in one direction, and I_{21} in the opposite direction.

The influence on the magnitude of the dark current of the direction in which it flows through the crystal was borne out in the number of tests. Diamond No. 1 was tried with both long and short ends pressed against the electrodes, and in both cases it was found that the large, dark current resulted when the current flowed in a definite direction through the crystal. Consistent results were obtained when both electrodes were pressed on face A, and on face B, of the crystal. While the ratios between dark currents in opposite directions varied greatly with change of position of the electrodes, the direction of maximum dark current in the crystal was preserved throughout.

[3]Streintz and Wessely, Phys. Zeitschr. 21, pp. 42-50, Jan. 15, 1920.

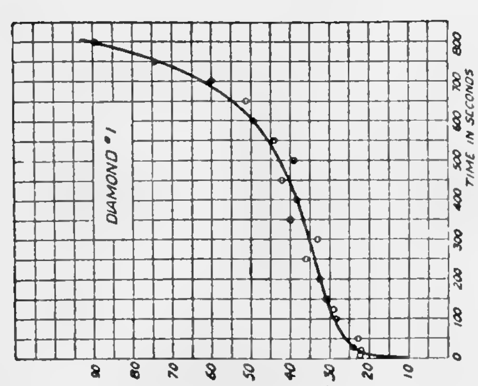

FIG. 7

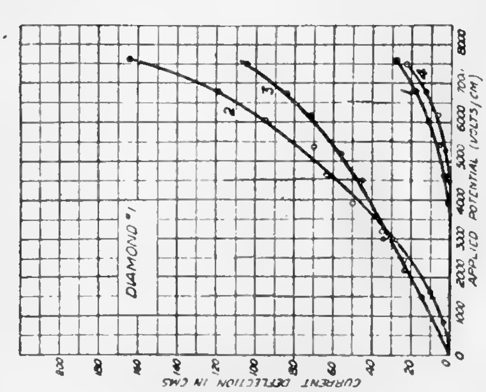

FIG. 9

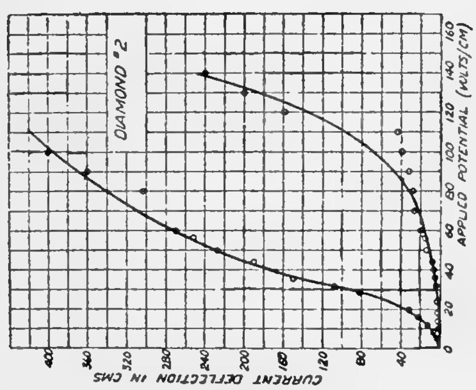

FIG. 10

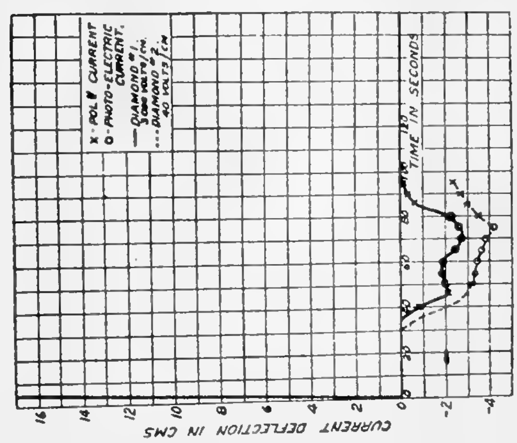

FIG. 12

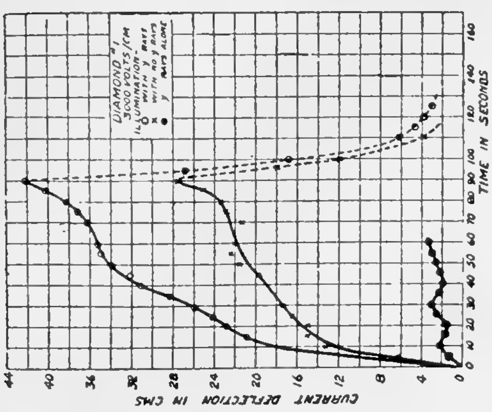

FIG. 13

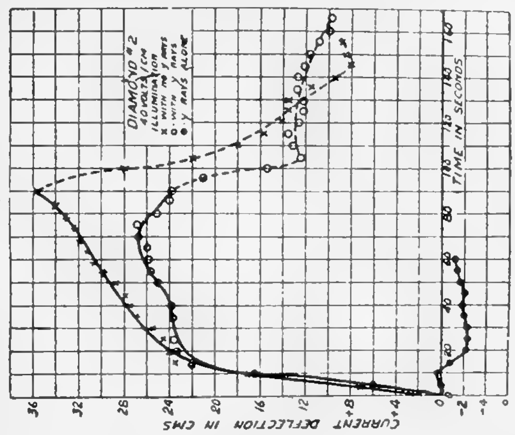

FIG. 14

The effect of varying the position of the electrodes on face A was investigated in a field of 4,000 volts per cm. It was found that in some positions of the electrodes the dark current in one direction was over 30 times that in the opposite direction, while in other positions there was no appreciable difference between the dark currents. In the latter case, however, the current obtained on illuminating the diamond was much larger in one direction than in the opposite, showing that the unidirectional property still existed, although the difference between the dark currents was not measurable. An illustration of the results is given in Fig. 11, which shows two positions of the electrodes on face A. In position "a," the dark current caused a deflection of 1.7 cms. in both directions, but on illumination the photo-electric current was 7.8 cms. in one direction and 2.5 cms. in the opposite direction. When the electrodes were moved a small distance to the position shown in "b," the dark current was 65 cms.

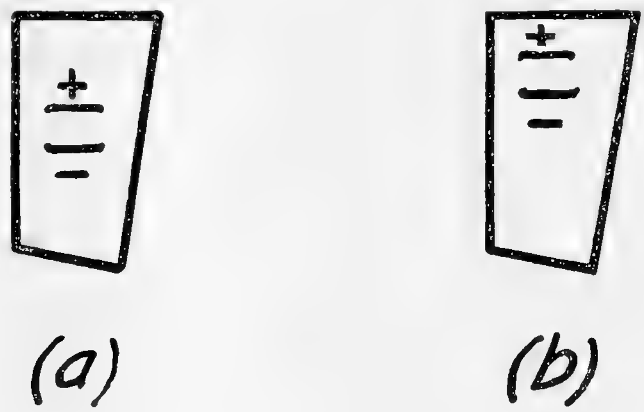

Fig. 11

in one direction, and only 3.5 cms. in the opposite direction. Here we have great variation in the dark current when the electrodes were moved a little way in the same straight line. It is possible that motion in this line may cause great alteration in the relative positions of the electrodes and the crystallographic axes, which may account for the variation in the magnitudes of the dark currents. In any case, it is evident that the unidirectional property for various regions of the crystal varied greatly in degree, but was always present.

Polarisation.

In view of the slow growth of the dark current, it was expected that the crystal would become polarised during the passage of the current, with consequent development of counter electromotive force in the crystal. An attempt was made to show this polarisation by subjecting the diamond to a high potential, suddenly cutting out the field and completing the circuit through the crystal. If the latter were polarised, the galvanometer would register a current in the direction opposite to that developed while the field was on.

The effect was shown by both diamond No. 1 and No. 2, much more markedly in the latter case. On the illumination of the diamonds, a photo-electric current flowed in a direction opposite to that which flowed when the external field was applied. The presence of this current proved conclusively the existence within the crystal of counter-fields of sufficient strength to develop a measurable photo-electric current under the influence of light. The results obtained are illustrated in Fig. 12.

Effect of Exposure to Gamma Rays.

Since it has been found that photo-sensitivity increased with decreasing wave-length of exciting radiation, it was thought to be of interest to find out the effect of radiation of very short wave-length, and therefore the crystals were exposed to gamma radiation. With diamond No. 1 it was found that a small photopositive current resulted on exposure to the gamma rays, but with diamond No. 2 the rays had a repressive effect, causing a very small photo-negative current. Fig. 13 and Fig. 14 illustrate the effect on the growth and decay of photo-electric current of exposing the crystals simultaneously to gamma radiation and to light. The repressive effect of the rays on the growth of the current in diamond No. 2 is to be noticed. The currents obtained on exposure to gamma rays alone are also shown in these figures.

5. Discussion.

(*a*) *Chemical Composition of Photo-sensitive Substances.*

Since it has been found that not all samples of diamond are sensitive to light, it is evident that photo-sensitivity is not intrinsically a property of a substance. The work of other observers also leads to this conclusion. Over 150 minerals have been examined by Case[4], and in his paper he lists, among others, Wulfenite, Greenockite, Sphalerite and Cinnabar as not being affected by illumination. On the other hand, Gudden and Pohl[5] have found samples of these minerals which are sensitive to a marked degree. Again, Case lists Galena as photo-sensitive, while Coblentz and Kahler[6] were able to

[4]T. W. Case, Phys. Rev. 2; p. 305, 1917.

[5]Gudden and Pohl, Zeitschr. fur Physik, 2, p. 361, 1920; also 5, p. 176, 1921.

[6]Coblentz and Kahler, Sci. Papers Bur. of Stands, No. 344, p. 247.

obtain no response to light with that mineral. Hence, it is clear that the cause of photo-sensitivity is not to be sought for in the chemical composition of a substance.

(*b*) *Spectral Absorption.*

An explanation of photo-electric conductivity is suggested by absorption, as it seems natural that the light absorbed would excite the carriers of electricity either by heating or resonance. For the validity of this explanation, it is necessary to have the maximum of photo-electric sensitivity coincide with the maximum of absorption, and also to have substances which are most absorbing, most photo-sensitive. Data obtained with the diamonds do not support this hypothesis, as it is seen by comparing Figs. 1 and 3 that the region of rising sensitivity in diamond No. 1 is one of falling absorption. Again, the diamonds that are opaque in the ultra-violet are not photo-sensitive.

On the other hand, the work of other observers indicates some relation between photo-electric conductivity and absorption. For example, it is known that the transparency of molybdenite increases considerably in the visible when it is cooled to liquid air temperature[7], and it has been shown that the maximum of its photo-sensitivity shifts from the infra red towards the visible when it is so cooled.[8]. Thus we have a corresponding shift of the maximum of transparency and of photo-sensitivity. Again, Coblentz[9] points out that, in considering the data on hand for a number of photo-sensitive substances, it is found that a gradual shifting of the absorption band from the ultra-violet into the infra-red is accompanied by a decrease in photo-sensitivity in the ultra-violet and an increase in the infra-red. That is, there seems to be a following up of the absorption bands by the bands of high photo-sensitivity. These considerations lead to the conclusion that there is some connection between absorption and photo-sensitivity, but the nature of this connection is by no means clear.

(*c*) *Fluorescence and Phosphorescence*

It has been seen that only diamond No. 1 is phosphorescent, and since diamond No. 2 also exhibits photo-electric conductivity, it cannot be said that phosphorescence is a necessary condition for photo-sensitivity. Of course, a general conclusion as to this matter cannot be based on the evidence from such a limited investigation.

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[7]Crandall, Phys. Rev. 2; p. 361, 1913.

[8]Coblentz and Kahler, Sci. Papers Bur. of Stands, No. 338.

[9]W. W. Coblentz, Sci. Papers Bur. of Stands, No. 412, p. 180.

That there is a connection between phosphorescence and photo-sensitivity is suggested by the investigation of Gudden and Pohl[10] on the behaviour of a compound Ca-Bi-Na phosphor. They found that the maxima of photo-electric sensitivity occur at the same regions of the spectrum as the maxima of the emission bands of the phosphorescence. Unfortunately, a parallel experiment could not be carried out with the diamonds, as the light emitted by their fluorescence was much too weak to permit of spectral analysis.

(*d*) *Index of Refraction*

The statement of Gudden and Pohl,[11] that a substance is photo-sensitive only in regions where its index of refraction is greater than 2, is of interest. The fact that diamond has a refractive index of 2.4, and has been found to be photo-sensitive, lends weight to this statement. Refractive indices for a number of photo-sensitive substances, as given in Groth's mineralogical tables, are found in the following table:

Substance	*Index of Refraction*	
Diamond	N_D.	2.41
Zinc Sulphide	N_D.	2.36
Cinnabar (Hg_2S)	N_D.	2.85
Cuprite (Cu_20)	N_R.	2.85
Wulfenite ($PbMo0_4$)	N_R.	2.40
Proustite (Ag_2AsS_2)	N_R.	2.97
Willemite ($Zn_2S_20_4$)	N_D.	1.71
Molybdenite (Mo_2S_3)	$N_{Infra\ Red.}$	2.85

The only substance in the above table which has a value less than 2.3 for its index of refraction is willemite, which was not found to be photo-sensitive. If, however, the quality of photo-sensitivity depended on the refractive index of a substance, there is no reason why one sample should possess it rather than another, and the cause of photo-sensitivity can not be attributed to the high index of refraction.

(*e*) *Dark Current*

On application of high voltages to the diamond for a long time, great irregularity manifested itself in the dark current in both directions. These irregularities are similar to those described above in the photo-electric currents, and point to the development of counter fields within the crystal. In fact, it seems clear that the irregularity

[10]Gudden and Pohl, Zeitschr. fur Physik, 3, p. 99, 1920; also 4, p. 206, 1921.
[11]Gudden and Pohl, Phys. Zeitschr., Oct. 15, p. 535, 1921.

observed in the photo-electric current need not be a property of the illuminated crystal, but may be due to the condition of the dark current. On illumination in this irregular condition, it was sometimes found that the photo-electric current flowed in a direction opposite to the normal one, indicating either a photo-negative effect or the presence in the crystal of counter fields greater in magnitude than the external field. The latter hypothesis appears more natural.

In the results recorded above, there is a clear relation between dark and photo-electric currents—large photo-electric current in the direction of large dark current, and irregularity in photo-electric current when there was irregularity in the dark current. It was also found that the diamonds which were not photo-sensitive were absolutely non-conducting in fields as high as 11,500 volts per cm. This indicates that the presence of a dark current is necessary for the existence of a photo-electric current. That this conclusion does not hold generally has been shown in work with some substances at very low temperatures, when the dark current almost vanished while the photo-sensitivity increased. It is usually true, however, that the magnitude of the photo-electric current depends on that of the dark current through the crystal.

(*f*) *Counter E.M.F. in Crystal*

In discussing photo-electric current, mention has been made of the analogy between the irregular secondary current of Gudden and Pohl, and the irregularity found with diamond on high voltage. It has also been pointed out that illumination of the crystal, when the dark current exhibited irregularity, sometimes resulted in an apparently photo-negative effect. In this connection it is interesting to point out the conclusions reached by Coblentz[12] in his work on the photo-negative properties of stibnite and molybdenite. Whereas Gudden and Pohl analyse the photo-electric current into two components:—the Primary, which is instantaneously established and prevails on low voltage, and the Secondary, which takes time to grow and prevails on high voltage—Coblentz comes to the conclusion that there are two contending forces acting Firstly, the one which causes photo-positive response acts quickly, prevails on low voltage and is similar to a resistance decrease; secondly, the one which causes photo-negative reaction grows slowly, is predominant on high voltage, and corresponds to the building up of a counter electromotive force. The analogy is striking between the photo-positive reaction and the

[12]W. W. Coblentz, Sci. Papers Bur. of Stands, No. 398, p. 624.

primary current, and between the photo-negative reaction and the secondary current. In the work with the diamond the effects obtained could be accounted for by the hypothesis of a counter electromotive force, the existence of which is demonstrated by the polarization currents in Fig. 15.

6. *CONCLUSION*

From the above considerations it is evident that there is no simple explanation for the phenomenon of photo-electric conductivity. It may be that the explanation lies in the crystal structure of the substance. Some weight is given to this idea by the fact that hammering a piece of photo-sensitive acanthite[13] rendered it entirely insensitive to light, while merely rubbing the surface of a piece of light sensitive molybdenite with a toothpick[14] decreased its sensitivity. In order to approach the problem from this angle an investigation of electrical conductivity in crystals, together with a sound knowledge of crystal structure, is necessary.

7. *SUMMARY*

1. Photo-electrical conductivity of two diamonds has been investigated. It has been found that there is considerable lag both in growth and decay of the photo-electric currents, and that the photo-electric sensitivity increases with decreasing wave-length of exciting light.

2. It has been found that the photo-sensitive diamonds exhibit the phenomenon of unidirectional conductivity, and the characteristics of the dark currents have been investigated.

3. It has been shown that on application of an electric field the diamonds become polarised, and that counter fields develop within the crystal.

4. On exposure to gamma rays, a photo-positive reaction was obtained with one diamond, and a photo-negative reaction with the other.

5. From considerations of the various properties of the crystals it has been shown that no simple explanation of the phenomenon has been reached, and it is suggested that the problem may be solved by consideration of crystal structure and conductivity in crystals.

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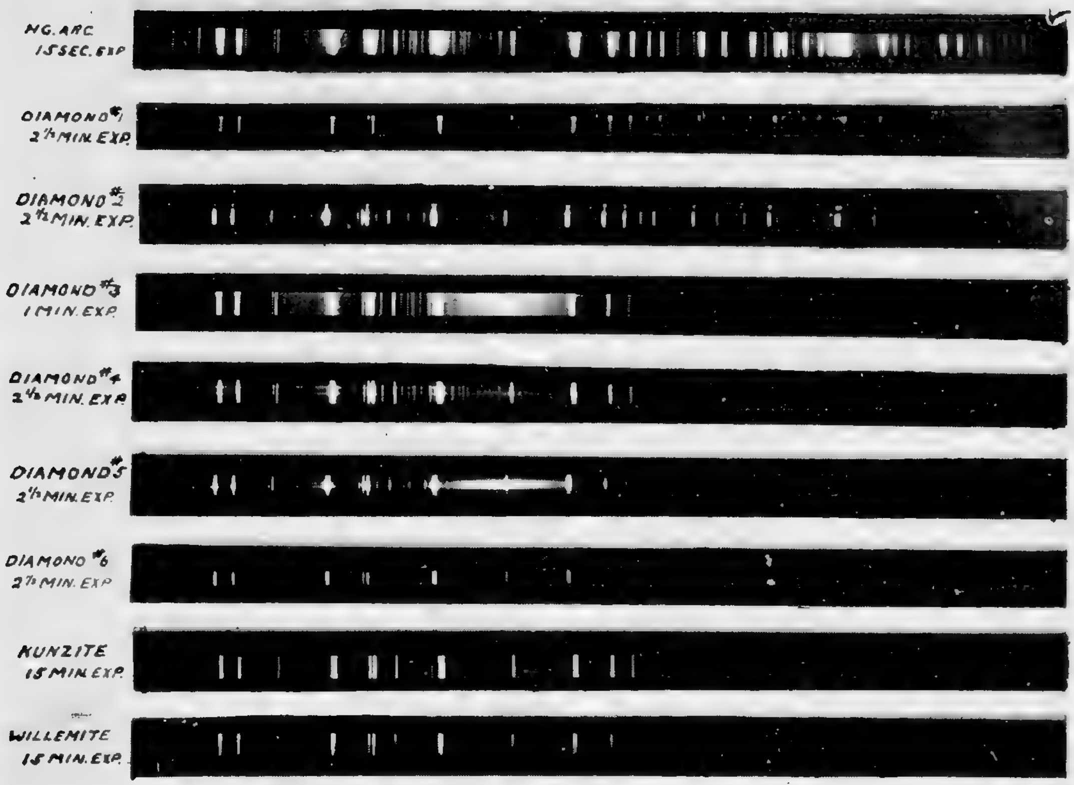
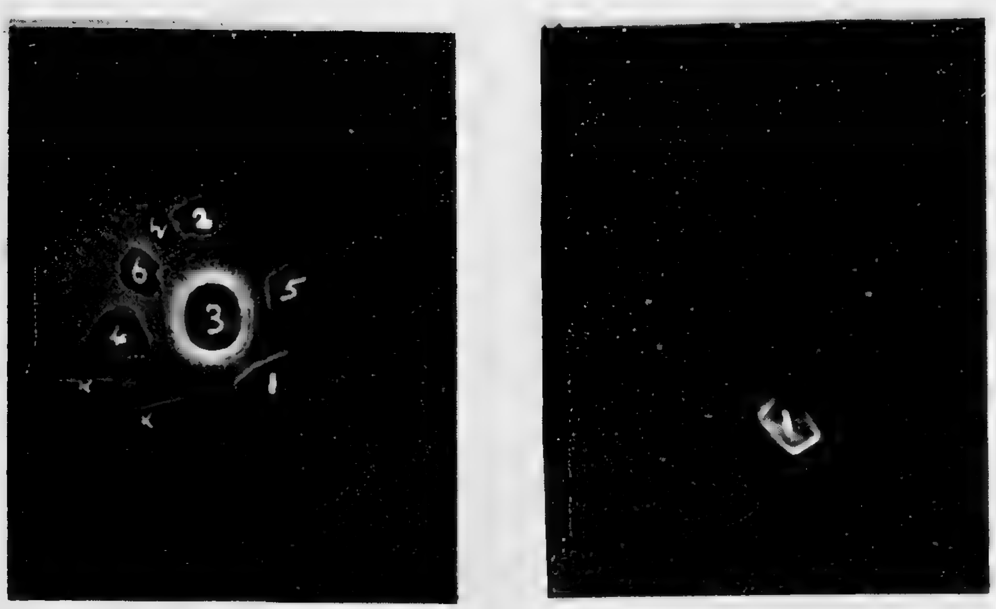
[13]Coblentz and Kahler, Sci. Papers Bur. of Stands, No. 344, p. 243, etc.
[14]Coblentz and Kahler, Sci. Papers Bur. of Stands, No. 338, pp. 152-153.

In conclusion, the author wishes to express her sincere thanks to Professor J. C. McLennan for suggesting the subject and directing the progress of the research. Thanks are also due to Messrs. Oppenheimer, of London, for their kindness in lending the diamonds used in this investigation.

Physical Laboratory,
University of Toronto.
May 15th, 1922.



SPECTRAL ABSORPTION OF CRYSTALS
FIG. 1



FLUORESCENCE. PHOSPHORESCENCE.

K-KUNZITE
W-WILLEMITE.

FIG. 2

The Destruction of the Fluorescence of Dilute Solutions by Ultraviolet Light

BY MISS F. M. CALE, B.A.,
University of Toronto

(Read May Meeting, 1922)

I. *Introduction*

The theory of luminescence as presented by Wiedemann[1] is in accord with many experimental results and has been accepted by scientists, generally, in some analogous form. By this theory the emission of fluorescent light accompanies either the expulsion or return of the ionized parts of the active centre. Fluorescence is then due to a permanent ability of the molecule to absorb indefinitely light of a certain wave-length and emit light of another.

In a paper describing the examination of thin films of fluorescent solutions Perrin[2] has presented an extremely interesting explanation of fluorescence. He has shown that an organic body is always destroyed when fluorescing, and assumes the destruction to be the cause of the fluorescence. The molecule does not then possess a permanent ability to emit light but gives a flash at the moment of transformation and is then rendered incapable of further fluorescence. Since all the fluorescent substances studied by him contained one or more benzene rings he has made the suggestion that the fluorescence may be due to the rupture of these rings.

Zinc sulphide has been found to be chemically changed and its power to phosphoresce decreased by the light that causes phosphorescence.[3] Exposure to a powerful oxidizing gas restored in part the original colour and ability to phosphoresce. Exposure to β rays[4], canal rays[5] and cathode rays[6] has also been known to cause the destruction of phosphorescence.

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[1]E. Wiedmann, Ann. d. Phys. 37, p. 177, 1889; E. Wiedemann and C. C. Schmidt, Ann. d. Phys. 56, p. 177, 1895.

[2]J. Perrin, Ann. d. Physique (IX) 10, pp. 133-159, Sept., Oct., 1918.

[3]L. B. Loeb and L. Schmiedeskamp, Nat. Acad. Sci. Proc., Vol. 7, pp. 202-207, July, 1921.

[4]E. Marsden, London Proc. Roy. Soc., 83A, pp. 549-561, 1910.

[5]H. Baerwald, Ann. d. Physik 37, 4, pp. 849-880, Nov., 1912; J. Bernd. Zs. Physik, Leipzig, pp. 42-44, 1920.

[6]Nichols and Merritt, Phys. Rev. Ithaca, 28, p. 349, 1909; Pospielow, Ann. d. Phys. 45, 7, pp. 1039-1062, No. 17, 1914.

An account of an investigation of the destruction of the fluorescence of solutions has recently been published by Wood,[7] who found that a fluorescent solution was generally transformed on exposure to sunlight to a coloured non-fluorescent liquid with a different absorption band. Continued exposure rendered the solution colourless. He has also shown that a fluorescent solution (rhodamine) may be bleached although prevented from fluorescing by maintaining at a temperature of 100°C. This would indicate that a transformation of the solution may not be as intimately connected with its fluorescence as supposed by Perrin.

It was thought to be of interest to make a photometric study of the rate of destruction of fluorescence during exposure to the exciting light.

II. *Apparatus and Method*

An aqueous solution of aesculin ($C_{15}H_{16}0_9$) was exposed in a test tube to the light of a mercury lamp. At regular intervals the solution was removed and its fluorescence compared with that of the original unexposed solution.

The quartz mercury lamp used to cause the solution to decay was 75 cms. in length and carried about 10 amperes. Although the light emitted by it was very intense the solution suffered only a slight rise in temperature, which could be neglected, as cooling took place at the intervals for testing the fluorescence.

Fig. 1 shows the arrangement of the apparatus for measuring the intensity of fluorescence for which a Nutting spectro-photometer was used. The light from a self-regulating carbon arc (A) was reflected downwards by a mirror into the two cells containing the fluorescent solutions to be compared. The fluorescent light from the cells passed through a stop (F) and entered the openings of the photometer, in a direction at right angles to the final direction of the exciting beam.

By varying the height of the stop the fluorescence at any depth of liquid could be measured.

In the experiments described below a stop 4 mm. in width was used and the intensity of the first 4 mm. of the liquid measured. The solutions used were sufficiently dilute to show no absorption and thus give a uniform image in the photometer.

A screen at G served as a black background for the fluorescent light and prevented the light of the arc from entering the photometer.

[7]R. W. Wood, Phil. Mag., pp. 757-765, 1922.

As the rays causing fluorescence were in the invisible region a nickel glass filter *H* was used which transmitted from $\lambda = 4078\ A$ to $\lambda = 3342\ A$ and a little in the extreme red. The visible light scattered by distilled water could be detected with a rested eye and was calculated to be only 1/1000 of the fluorescent intensity of the standard aesculin solution.

Any slight variation in the intensity of the arc affected both solutions in the same way as the intensity of fluorescence varies directly with the intensity of the exciting light. This has been verified recently for extremely great intensities.[1]

III. *Experiments*

Preliminary experiments were made to test the sensitivity of the instrument. The standard solution was taken as 4/100,000 and the intensity of fluorescence of solutions as dilute as 1/10,000,000 could be detected and measured.

The spectrum of the blue fluorescent light emitted by the aesculin solution is shown in Plate 1A. It is seen to be a broad band extending from about $\lambda = 5461\ A$ to $\lambda = 4078\ A$. As quartz was used for all the optical apparatus ultraviolet fluorescence, if present, would have appeared. The mercury light used to excite fluorescence was reflected from the walls of the vessel giving the line spectrum shown.

On long expousre to the ultraviolet light the solution was transformed from a colourless liquid exhibiting a bright blue fluorescence to a pale amber-coloured non-fluorescent liquid.

The fluorescing solution had an absorption band in the extreme ultraviolet and another with a maximum about $\lambda = 3400\ A$ (Plate 1B). The latter absorption indicates the removal of the light causing fluorescence from the incident beam and is not present in the absorption spectrum of the decayed solution. The wave-length of the exciting light is seen to be shorter than the wave-length of the fluorescent light, thus verifying Stokes' Law in the case of aesculin. No intermediate stage with an absorption band differing slightly from that of the fluorescing solution as found by Wood for some fluorescent substances was detected in this case.

A solution was exposed to ultraviolet light for about 2 hours and measurements of the fluorescent intensity made every 15 minutes. After removing to a dark room for several hours the excitation was resumed. A characteristic set of readings is given in Table 2 (I and II) and Fig. 4. From the graph it is seen that the fluorescent intensity was less after the period of rest than at the cessation of exposure.

[8]R. W. Wood, Phil. Mag., pp. 757-765, April, 1922.

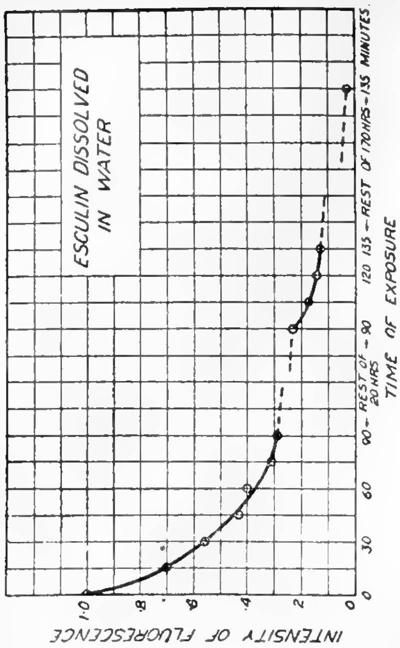


FIG. 4

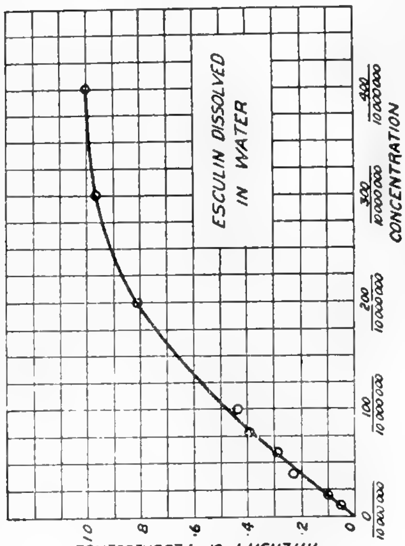


FIG. 3

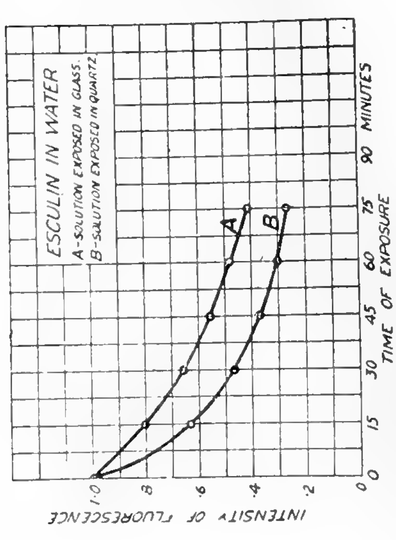


FIG. 2

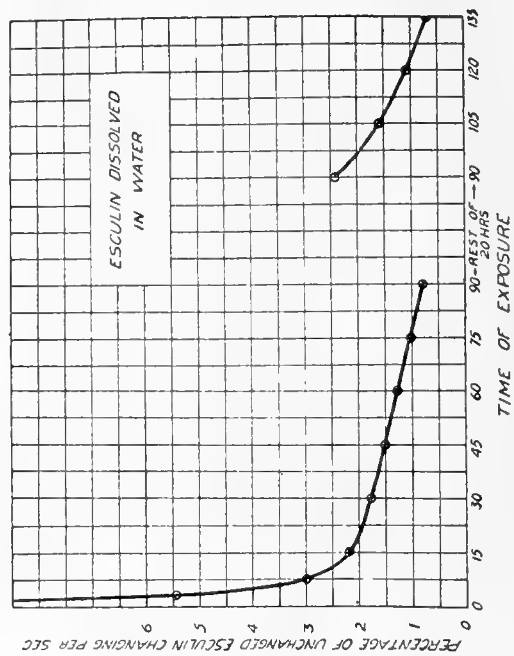


FIG.6

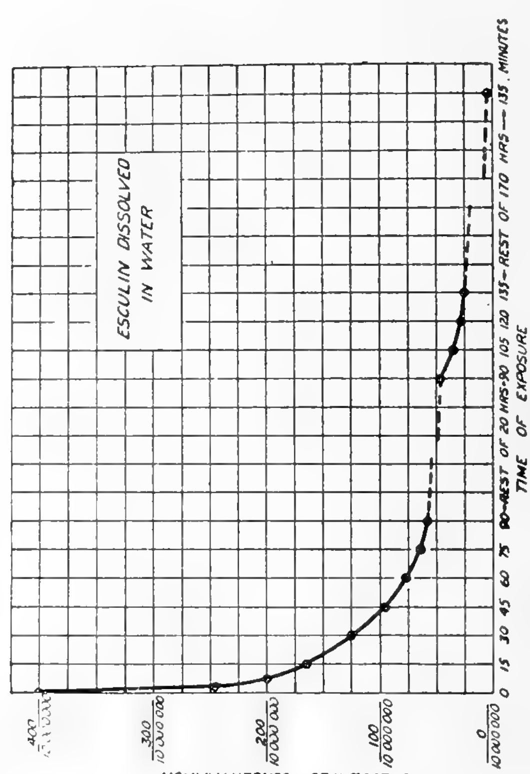


FIG. 5.

TABLE 1

Strength of Solution x 10^7	Intensity of Fluorescence
400	1.0
300	.96
200	.81
100	.43
80	.39
60	.29
40	.23
20	.10
10	.06
1	.005

TABLE 2

I	II	III	IV	V
Length of exposure min.	Intensity of fluorescence	Calculated concentration x 10^7	Change in concentration per sec. x 10^7	% of aesculin changing per sec.
3	.90	245	13.33	5.44
7.5	.81	200	5.93	2.96
15	.70	165	3.61	2.18
30	.56	125	2.24	1.79
45	.45	97	1.47	1.52
60	.87	78	1.01	1.29
75	.32	66	.680	1.03
90	.29	58	.451	.78
90	.23	47	1.123	2.39
105	.17	34	.545	1.60
120	.14	28	.303	1.08
135	.13	26	.175	.67

Even a short exposure was sufficient to commence an operation which caused complete decay within a few weeks for very dilute solutions. Stronger solutions required two or three months. The rate of decay in the dark was too small to exhibit any luminescene.

Solutions exposed in quartz and glass gave curves of decay of intensity of the same form, but as the glass only transmitted above $\lambda = 3342A$ some of the rays causing fluorescence were not available in the case of glass and the rate of decay was about half of that in the quartz (Fig. 2).

A set of about 12 solutions with different known concentrations was carefully prepared and measurements of their fluorescent intensity taken within a day or two to avoid any complications due to decay of the solutions. The usual form of curve was obtained (Table I, Fig. 3). For very dilute solutions the intensity was proportional to the concentration but reached a maximum for higher concentration.

An experiment was made to detect the effect of the presence of the decayed solution on the fluorescent power of the unchanged molecules. Solutions were diluted the same amount, one by the addition of distilled water, the others by the addition of decayed solution of varying strengths.

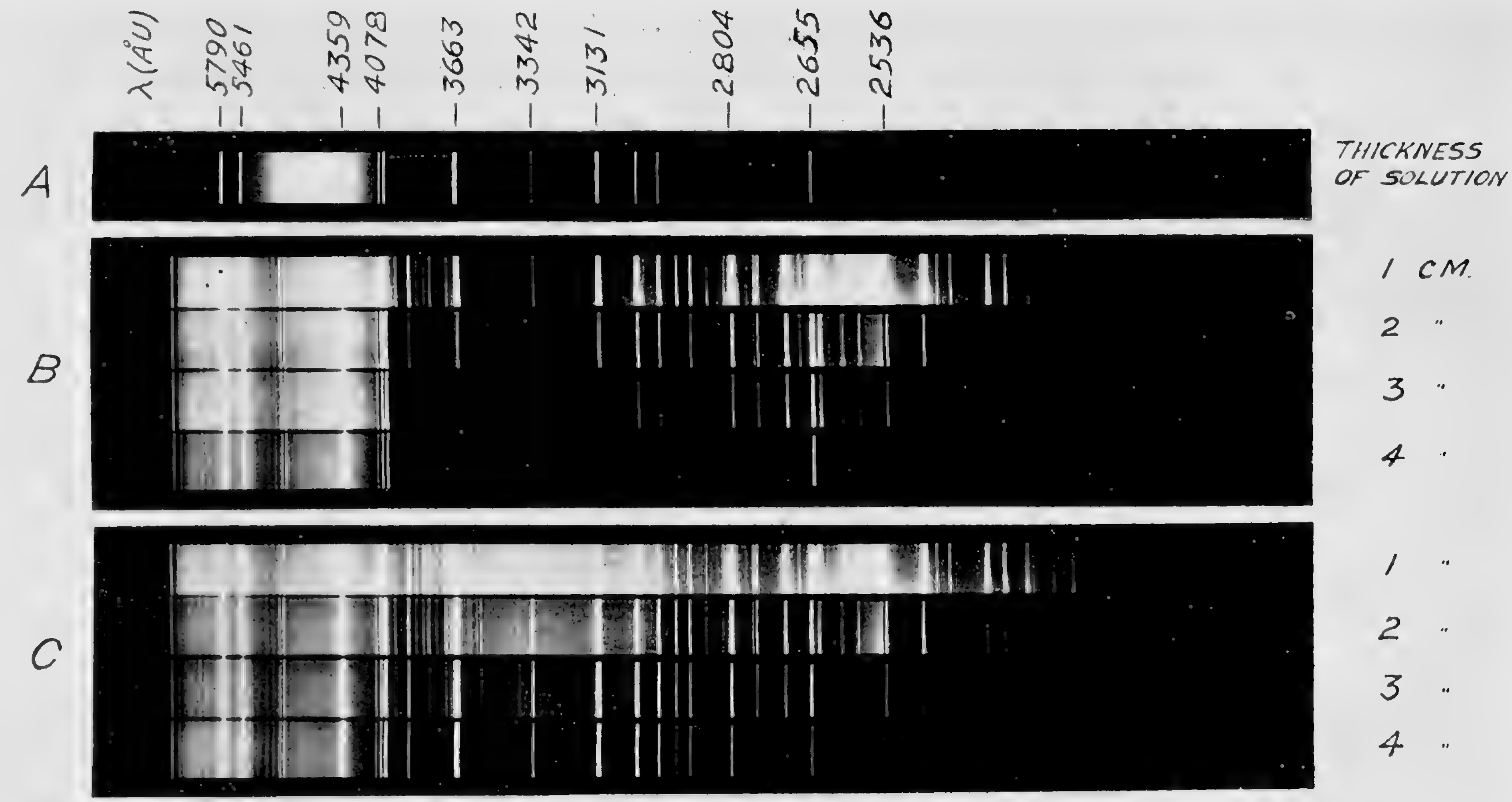
As the fluorescence was equal in all cases, the fluorescent power was taken to be unchanged by the presence of transformed molecules and the intensity of fluorescence of any solution was assumed to be an indication of the number of unchanged molecules present. Values of the concentration during the exposure were obtained from Fig. 3, and a graph plotted (Table 2, III, Fig. 5). It is seen that the number of molecules transformed was very large at first, and decreased as the exposure continued and the solution became weakened by the ultra violet light.

By drawing tangents to this curve a calculation was made of the percentage of the molecules present transformed per sec. One would suppose that after the solution became very dilute the light would penetrate the entire solution and the percentage transformed per sec. would be constant, but Fig. 6 shows the rate to decrease very rapidly at first, then steadily. Perrin has found that for very concentrated solutions the rate of change is slow, increasing as the concentration is lessened by the decay of the fluorescent particles.

These results would lead one to believe that the rate would increase to a maximum, then decrease as the concentration becomes dilute.

Further examination of Fig. 6 shows that on recommencing the exposure after a rest of several hours the rate of decay was much more rapid than before the interval, although the fluorescent intensity had weakened in the meantime. The rate of change is then not merely a function of the concentration but depends also on the duration of exposure. A slight extension of Perrin's theory would be necessary to account for this.

It was found that the fluorescence of aesculin could also be destroyed by bubbling ozone through the solution. The reaction proceeded at the same rate whether ultraviolet radiation was present



A – FLUORESCENT SPECTRUM OF ESCULIN IN WATER.
B – ABSORPTION SPECTRUM OF UNEXPOSED ESCULIN SOLUTION.
C – ABSORPTION SPECTRUM OF DECAYED ESCULIN SOLUTION.

PLATE I

or absent, and complete transformation was brought about in six or seven minutes. The decayed solution had a similar colour and absorption spectrum (Plate 1C) to the solution decayed by ultraviolet light.

The addition of a little acid to an aesculin solution caused the destruction of the fluorescent substance. A few drops of hydroxide restored the fluorescence of this liquid, but were unable to restore the solutions transformed by ozone or ultraviolet light.

An attempt will be made to ascertain whether the transformation by ozone is a reaction similar to, or the same as, that brought about by ultraviolet light. Although no definite conclusion can be deduced it is felt that a more prolonged investigation in this direction should be of interest and lead to fruitful results.

Summary

1. Measurements were made on the decrease of fluorescent intensity on exposure to ultraviolet light.

2. After the solution was once exposed it continued to decay although kept in absolute darkness.

3. On exposing to ultraviolet light the rate of decay decreased very rapidly at first, then steadily.

4. On recommencing the exposure after an interval of several hours the rate of decay was more rapid than before the interval.

5. Ozone caused a very rapid decay, producing a solution similar to that transformed by ultraviolet light.

This work was carried out under the direction of Professor J. C. McLennan, to whom the writer wishes to express her sincere thanks for his interest and helpful suggestions.

Physical Laboratory,
University of Toronto.
May 15th, 1922.

The Intermediate Compounds in the Reaction between Phthalic Anhydride, Aluminium Chloride and Aromatic Hydrocarbons

By T. C. McMULLEN, M.A.

Presented by PROFESSOR F. B. ALLAN, F.R.S.C.

The first intermediate compound in the reaction between phthalic anhydride, benzene, and aluminium chloride when treated, in benzene solution, with naphthalene gave a 35% yield of naphthoyl-benzoic acids. If ether be added to the benzene solution of this first intermediate compound a heavy oil is precipitated which gives benzoyl-benzoic acid and no naphthoyl-benzoic acids when treated with naphthalene.

The second intermediate compound, which is insoluble in benzene, when prepared from phthalic anhydride, benzene, and aluminium chloride and treated with naphthalene and acetic anhydride gave an 80% yield of the naphthoyl-phenylphthalides most of which was the β-naphthoylphenylphthalide. Attempts to prepare these phthalides from the intermediate compounds prepared from phthalic anhydride, naphthalene, and aluminium chloride by adding benzene and acetic anhydride were unsuccessful. Various derivatives of these mixed phthalides were also prepared.

In the course of this investigation nine new compounds were prepared.

Concentration changes at the Cathode during Electrolysis of Acid Solutions of Copper Sulphate

By PROFESSOR J. T. BURT-GERRANS and A. R. GORDON, B.A.

Presented by PROFESSOR W. LASH MILLER, F.R.S.C.

In continuation of the work of Mr. L. V. Redman in this laboratory[1] oscillographic measurements have been made of the interval of time that elapses between closing the circuit and evolution of hydrogen at the cathode during electrolysis of acid solutions of copper sulphate. Special precautions were taken to ensure a uniform

[1]Trans. Roy. Soc. Can., 1908, Sec. III., p. 244.

electrical and hydrostatic field. Time, rate of revolution of the cathode, current, and voltage over the cell, were recorded on each of the photographic films.

Solutions of various concentrations of copper sulphate and of acid were used. The temperature and the rate of revolution of the cathode were varied. The current was continuous, interrupted, abruptly raised or lowered, abruptly alternated, sinusoidal, or sinusoidal with superposed direct current; and in the case of abrupt change the lengths of the various "beats" were varied.

In every case the interval before evolution of hydrogen agreed within a few percent with that calculated from the equations deduced by Professors Rosebrugh and Lash Miller in their paper on the mathematical theory of concentration changes at the electrodes;[2] the assumptions made in that paper must therefore be regarded as verified by experiment.

The Electrolysis of Aqueous Solutions of Sodium Sulphide

By W. R. FETZER, M.A.

Presented by PROFESSOR W. LASH MILLER, F.R.S.C.

As a preliminary, the methods of determining the various sulphur acids in solutions containing mixtures of their sodium salts were revised, and new methods introduced. Using these analytical methods it was found that when solutions of sodium polysulphides are electrolysed in an atmosphere of nitrogen, with rotating platinum anode, and a diaphragm to keep out the cathode solution, the only product at the anode is polysulphide sulphur, exactly 16.00 grams being formed for every faraday of electricity passed through the solution. This holds unless the current density is great enough to cause deposition of free sulphur as a yellow deposit, whereupon sulphate and dithionate of sodium are formed.

The current density necessary to bring about this deposition of sulphur was then studied as a function of the rate of rotation of the anode and the composition of the electrolyte, and it was found that by dissolving sulphur in a solution of sodium sulphide the current needed to cause deposition of sulphur is first *increased*, passes through

[2]The Journal of Physical Chemistry, vol. 14, p. 816–844 and Trans. Roy. Soc. Can., 1913, Sec. III., p. 210.

a maximum when the ratio of monosulphide sulphur to dissolved (polysulphide) sulphur is about 1 to 1.7, and then falls off to zero as the solution approaches saturation with sulphur. These results have an important bearing on the theory of periodic phenomena at the anode discovered by Küster.

The Reactions of Zircon in the Electric Furnace

By I. M. Logan, B.A.Sc.

Presented by Professor W. Lash Miller, F.R.S.C.

Heated in shallow graphite trays in a resistance-type crucible furnace to 1800°, zircon is converted into silica and zirconium oxide; this reaction may be observed at temperatures as low as 1600°.

Heated with carbon, it is converted into zirconium carbide mixed with a small proportion of zirconium silicide. Heated with silicon in a carbon crucible in the high frequency induction furnace, much more carbide than silicide is formed. Heated in an atmosphere of nitrogen, in a shallow graphite dish, fumes of silica are given off, and the residue contains zirconium carbide but no nitride.

These experiments were carried out under the direction of Professor J. T. Burt-Gerrans.

The Characteristics of Electric Furnace Arcs

By A. E. R. Westman, B.A.

Presented by Professor W. Lash Miller, F.R.S.C.

An arc "characteristic" is a curve shewing the relation between current and voltage for an arc of constant length; it depends on the material of the electrodes, that of the cathode usually being the more important. Mrs. Ayrton has determined the characteristics of arcs between carbon electrodes up to half an inch in diameter, and currents up to thirty amperes; practically no work has been done with heavier currents or larger electrodes. In the present investigation currents up to nine hundred ampres were employed.

With these heavy currents special precautions had to be taken to shield the arc against air currents and magnetic disturbances. "Humming arcs," in which the luminous portion enlarges and contracts periodically, and the voltage oscillates correspondingly, were avoided by rasping off the tip of the cathode. "Groaning arcs," a new form of unsteady arc, in which the white hot anode spot jumps up and down between the bottom and the edge of the crater, were avoided by cutting the electrodes to the proper shape, using a template.

The effects on current and voltage caused by raising or lowering the cathode a few millimetres were measured; and from these results by integration, the effect of the length of the arc. The "constants of integration" were obtained by measuring clay models of the space between the electrodes.

In connection with these measurements it has been found, contrary to expectation, that it is possible to maintain an arc with a potential difference as low as twenty volts; in fact, the use of the twenty volt arc has been introduced as part of the routine of building up the current.

The Melting Interval of certain Undercooled Liquids

By Professor John Bright Ferguson

Presented by Professor W. Lash Miller, F.R.S.C.

In 1916, McIntosh and Edson (J. Am. Chem. Soc. *38*, 613), reported that solids produced by the sudden chilling of certain aqueous solutions did not behave on melting in a normal fashion. They found that the melting points of this material corresponded to the points on the liquidus curves on the phase rule diagrams of these solutions. Constant temperature baths were prepared by them by the use of such substances.

We repeated some of their experiments in the hope of obtaining some inkling as to the explanation of the phenomenon and also because we did not believe that this method of obtaining a constant temperature bath was of general application. We found that the constant temperature obtainable with a given salt solution was somewhat dependent upon the experimental proceedure and did not always correspond to the liquidus temperature as they had held to be the case. The constant temperatures may be explained by a consideration of the magnitudes of the heats of melting and re-crystallization and the velocity with which the melting and the re-crystallization take place.

The Effect of Acids on the Rate of Reproduction of Yeast

By MISS E. TAYLOR, B.A.

Presented by PROFESSOR W. LASH MILLER, F.R.S.C.

Nitric, hydrochloric, sulphuric, acetic, oxalic, tartaric, glycollic, lactic, or chloracetic acids were dissolved in various proportions in wort, or in mixtures of wort and sugar-salt solutions, or in various artificial media containing different preparations of bios. In each case the *PH* value was determined, and the rate of reproduction of yeast under suitable conditions of temperature and stirring. The *PH* values at which reproduction is checked are very different for the different acids in the same nutrient solution, and also for the same acid in different media.

The Quantitative Determination of Bios

By G. H. W. LUCAS, B.A.

Presented by PROFESSOR W. LASH MILLER, F.R.S.C.

When a small seeding of yeast is introduced into a nutrient solution consisting of ten per cent. of wort and ninety per cent. of a sugar-salt solution, and the whole is shaken in a thermostat at 25°C., the number of yeast cells increases logarithmically until it reaches about 145 million cells per cubic centimeter and then remains constant. As the alcohol concentration when reproduction ceases is too low to affect the yeast, the cessation of reproduction was ascribed by Mr. Clark[1] to exhaustion of the bios from the nutrient solution.

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[1]Trans. Roy. Soc. Can., 1921, Sec. III., pp. 47; and Jour. Phys. Chem., vol. 26, pp. 42–60.

This conclusion has been checked by examining the filtrate from maximal cultures of yeast in media containing various proportions of wort; from solutions containing ten per cent. or less, the filtrate contains no bios; there is a little bios left in the filtrate from twenty per cent. solution, in this case reproduction has been checked by the alcohol formed; similarly with higher percentages up to pure wort. The amount of bios in one litre of wort is thus shewn to be sufficient for the rapid growth of about 280 grams of yeast.

These results have been used to standardize the method proposed by Mr. Clark for the quantitative determination of bios, and the method has been used to check the losses which occur during the production of concentrated preparations of bios.

The Reaction of Acenaphthene with Phthalic Anhydride and Aluminium Chloride

By F. Lorriman, B.A.

Presented by Professor F. B. Allan, F.R.S.C.

Naphthalic anhydride with benzene and aluminium chloride gave naphthalic acid only, and 4-bromnaphthalic anhydride with benzene and aluminium chloride gave only 4-bromnaphthalic acid.

Phthalic anhydride with aluminium chloride and acenaphthene in benzene solution gave a good yield of an acid whose silver salt contains 33.1% silver. When 5-bromacenaphthene is used instead of acenaphthene an acid is obtained which will be further investigated.

Some Derivatives of Maleic and Fumaric Acids

By H. Oddy, M.A.

Presented by Professor F. B. Allan, F.R.S.C.

Rubidge and Qua's method for the preparation of aromatic lactones gave negative results when maleic anhydride, benzene and aluminium chloride were used. Several new derivatives of acrylic acid have been prepared by using maleic anhydride, aluminium chloride and naphthalene, anthracene, and diphenyl, respectively.

Fumaryl chloride with benzene and aluminium chloride gave dibenzoyl-ethylene (trans); when toluene was used instead of benzene the product was di-p-toluylethylene (trans) and when m-xylene was used the product was di-2,4-xylylethylene (trans).

Preparation of Dust-free Liquids

By C. M. Anderson

Presented by Professor F. B. Kenrick, F.R.S.C.

The difficulty of preparing dust-free liquids by filtration through collodion films appears to be due to a disintegration of the film itself after some hours use. Water has been prepared almost dust-free by the use of a film supported by a fine mesh wire screen, with an automatic syphon by means of which sufficient rinsing of the receiver could be effected before the disintegration of the film began.

Supersaturated Solutions of Gases

By K. L. Wismer, B.A.

Presented by Professor F. B. Kenrick, F.R.S.C.

It was hoped that the slow formation of bubbles from supersaturated aqueous solutions of gases would be more easily controlled and followed than the more violent vaporization of superheated liquids, and that in this way some clue to the cause of bubble formation would be obtained. Solutions of oxygen and of carbon dioxide were investigated at atmospheric pressure at concentrations corresponding to pressures up to about 50 atmospheres in the case of oxygen and 35 in the case of carbon dioxide. The results obtained up to the present seem to justify the following conclusions:

1. A long heating of tube and solution at high temperature was found to favour supersaturation.

2. The time interval between the reduction of pressure and appearance of a bubble varies between wide limits even under apparently identical conditions.

3. Suspended particles (e.g. colloidal platinum) introduced into the liquid rapidly lose their effectiveness in starting the bubbles.

4. It is almost certain that in all cases the bubbles were initiated at the surface of the glass, although the location on the surface was by no means constant except in tubes in which there were obviously imperfections in the glass.

5. Although carbon dioxide is nearly thirty times as soluble as oxygen, the average time interval before formation of bubbles is about the same for these two gases at the same temperature when the supersaturation corresponds to the same equilibrium pressure.

6. On the assumption that the bubble originates from a spherical particle acting as a nucleus which the bubble just encloses, the diameter of such a particle was calculated to be at most 5×10^{-7} cm.

The Behaviour of Glass on Electrolysis

By J. W. Rebbeck, B.A.Sc., M.A.

Presented by Professor W. Lash Miller, F.R.S.C.

Experiments have been carried out on the electrolysis of glass at temperatures ranging from 75 to 160°C. and with differences of potential varying up to 220 volts per mm. thickness of glass. These experiments indicate that under certain conditions gas may be developed and that by changing these the phenomenon can be reversed. Preliminary analysis of this gas indicates that it mainly consists of hydrogen. Further experiments are under way with a view of ascertaining the nature of the phenomenon. These experiments were carried out under the direction of Professor J. B. Ferguson.

The Diffusion of Hydrogen and of Helium through Silica Glass

By Glenn A. Williams, B.S., M.A.

Presented by Professor W. Lash Miller, F.R.S.C.

In the following table are collected some of the results we obtained with different samples of silica glass. The rates listed are the rates per hour in cc. (0° and 760mm.), at which the gas in question at atmospheric pressure passes through a glass wall one sq. cm. in area and one mm. thick into a vacuum.

Temperature	Hydrogen	Helium
180°C.	....	3.8×10^{-4}
440	1.6×10^{-4}	40. "
"	1.5 "	....
"	1.7 "	....
610	5.15 "	120. "
"	4.6 "	107. "
"	6.2 "	....
727	8.0 "	....
"	7.7 "	....
881	17.7 "	....
"	15. "	....

The several values given for each temperature were obtained on different samples of silica glass. We also observed that helium would pass through pyrex glass at 610°C.

These experiments were carried out under the direction of Professor J. B. Ferguson.

Stability Relations of the Lower Oxides of Iron

By D. M. Findlay, B.A., and I. Hoover

Presented by Professor W. Lash Miller, F.R.S.C.

This is an extension of the work reported last year by Findlay, Noble and Robertson. Known gas mixtures of hydrogen and water vapour were passed for six hours over a suitable charge of iron or iron oxide at a temperature of 750°C. Pure reduced electrolytic iron was used as a starting point. For gas compositions having a ratio of hydrogen to water vapour of 1.85 or higher the iron did not oxidize while with compositions having a ratio of 1.76 or lower the iron did oxidize. These results are a close check upon the recent work of Chaudron which, though obtained by an entirely different method, lead to a value of 1.85 for the constant of the iron-ferrous oxide equilibrium at this temperature. Eastman's calculation of this equilibrium from the measurements obtained on the system CO-CO_2-Fe-FeO leads to a value 2.25 for this temperature and he was somewhat skeptical of the work on this system as a result. Our work would suggest that the phases present in the two systems at equilibrium may not be identical. One measurement with an iron powder containing some oxygen and a little carbon showed oxidation with a gas of ratio of 2.0. Further experiments of this type will, we hope, shed light on the discrepancy which now exists.

We have been unable to obtain evidence that pure iron takes up ferrous oxide in solid solution at 700, 750 or 960°C. We find that the solid solutions of magnetite in ferrous oxide extend to a composition containing 76% iron at 750°C. These latter results are in agreement with those of F., N., and R. and also with those of Matsubara. On the other hand Matsubara interpreted his other results as meaning that iron took up large quantities of ferrous oxide in solution. A more probable explanation of these results can be given and this explanation may be extended to cover his results on the $FeO-Fe_3C$ equilibrium and also the results of most of the workers in the iron-carbon-oxygen field. It also sheds new light on the iron-carbon system.

These experiments were carried out under the direction of Professor J. B. Ferguson.

The Electrodeposition of Copper and of Nickel on Aluminium

By T. E. Everest

Presented by Professor W. Lash Miller, F.R.S.C.

It has often been attempted, without success, to deposit electrolytically an adherent coating of copper or other metal on aluminium. The difficulty seems to have been caused by the insufficiency of the methods hitherto employed for cleaning and preparing the aluminium surface. We find that if the surface to be plated is first made anode in a solution of sodium hydroxide, rinsed, and transferred without delay either to a cyanide-copper bath, or to an acid-copper bath, the film of copper electrolytically deposited is adherent, will resist bending until the aluminium fails, and will stand hammering, or heating to 200°C., without loosening. An adherent coating of nickel may also be easily deposited, if the aluminium surface is prepared as described.

The following procedure has proved satisfactory. The aluminium surface is first brushed with a steel scratch brush, then joined to the positive terminal, and immersed in an aqueous solution containing about 18 grams of sodium hydroxide per litre, a current of about 4 amperes per square decimetre, at 45 volts being passed for 12 minutes.

These experments were carried out under the direction of Professor J. T. Burt-Gerrans.

The Determination of Phosphorus in Phosphor Bronze, and a Note on the Determination of small amounts of Zinc

By MISS F. M. BURWASH

Presented by PROFESSOR W. LASH MILLLR, F.R.S.C.

A comparative study of the methods for determining phosphorus in bronze led to the conclusion that the short method of Greenwood gives just as accurate results as the much longer and more tedious procedure of Griffith and Heath.

To the bronze is added a gram of mild steel whose phosphorus content is known. The whole is dissolved in aqua regia, nearly neutralized, and the analysis finished exactly as in the case of high phosphorus steels, except that the excess of potassium permanganate is reduced with hydrochloric acid.

Attempts to separate small quantities of zinc from low grade ores and slags, by precipitation as ferrocyanide, were unsuccessful on account of the difficulty of purifying the precipitate without formation of colloidal solutions.

These experiments were carried out under the direction of Professor L. J. Rogers.

Light Scattering by Dust-free Liquids

By W. H. MARTIN, M.A.

Presented by PROFESSOR F. B. KENRICK, F.R.S.C.

The ratio of exciting to scattered light has been measured for the mercury blue, mercury green and sodium yellow lines. A comparison of these ratios shows that the intensity of the scattered light varies inversely as the fourth power of the wave length.

The light absorption of dust-free water and benzene has been determined for various wave lengths and found to be considerably greater than the amount accounted for by scattering alone. The absorption for water was considerably less than that found by previous investigators. Even in the region of the spectrum where water possesses the greatest transparency the scattered light is only one fourth of the total light absorbed.

Light Scattering; Bibliography

By W. H. MARTIN, M.A.

Presented by PROFESSOR F. B. KENRICK, F.R.S.C.

The literature on light-scattering has grown very rapidly during the last few years. Several bibliographies are to be found which are concerned with certain phases of the subject but none of these covers the whole field. It is intended that the following reference list, in so far as the earlier work is concerned, shall serve only as an index to the other bibliographies and books of reference. It is hoped, however, that the list of references to the more recent laboratory work on scattering in homogeneous media is fairly complete and that the nature of each article is made apparent. It is already evident that these experimental results will be extensively used in molecular physics as a basis for hypotheses regarding the constitution of matter and the nature of light.

1. EARLIER THEORIES OF LIGHT-SCATTERING.

For review and bibliography see NICHOLS: Phys. Rev., **26**, 497 (1908).

2. LATER THEORIES OF LIGHT-SCATTERING.

A. *Lord Rayleigh's theory.* This theory underlies all theories of light-scattering which have survived.

LORD RAYLEIGH: Phil. Mag., **41**, 107, 274 and 447 (1871); (5) **12,** 86 (1881); **47,** 375 (1899).

Many papers have appeared in amplification of the Rayleigh theory. For review of theory of scattering in relation to general theory of light-propagation see NATANSON: Phil. Mag., **38,** 269 (1919).

B. *Smoluchowski's theory.* A special theory developed on the basis of Rayleigh's theory, but more general in that it is applicable to liquids and solids as well as gases, and in the case of gases which obey Boyle's law is equivalent to Rayleigh's theory.

SMOLUCHOWSKI: Ann. der Phys., **25**, 205 (1908).

KAMERLINGH-ONNES and KEESOM: Comm. from the phys. lab. at Leiden, No. 104b, republished in Amst. Proc., **10**, 611 (1908), also in Ann. der Phys., **35**, 591 (1911).

EINSTEIN: Ann. der Phys., **33**, 1275 (1910).

KING: A modification of the Smoluchowski formula, but differing from it in an important respect. Read before Royal Society of Canada, Section III., May 1922, and to be published elsewhere.

C. *Cabannes' correction factor* for use in either of the above theories in case the scattered light is incompletely plane-polarized.

CABANNES: Jour. de Phys., (6) **1**, 129 (1920); Ann. de Phys., **15**, 5 (1921).

3. RECENT LABORATORY OBSERVATIONS ON THE SCATTERING OF LIGHT BY HOMOGENEOUS MEDIA.

A. *Gases.*

CABANNES: Comptes rendus, **160**, 62 (1915); **168**, 340 (1919); Ann. de Phys., **15**, 5 (1921). This last article is the best general review of the whole field of molecular scattering.

SMOLUCHOWSKI: Bull. de l'Acad. des Sc. de Cracovie, page 218, A, (1916).

R. J. STRUTT (LORD RAYLEIGH): Proc. Roy. Soc., **94A**, 453 (1918); **95A**, 155 (1919); Nature, **104**, 412 (1919); Proc. Roy. Soc., **97A**, 435 (1920); **98A**, 57 (1920).

GANS: Ann. der Phys., **65**, 97 (1921).

B. *Liquids.*

(*a*) Controversy as to whether dust-free liquids scatter light.

LALLEMAND: Comptes rendus, **69**, 1294 (1869).

SORET: Ibid., **69**, 1192 (1869).

SPRING: Rec. Trav. chim. Pays-Bas., **18**, 153 and 233 (1899).

LOBRY DE BRUYN: Ibid., **23**, 155 (1904).

LE BLANC and KANGRO: Zeit. Elektrochemie **19**, 794 (1913); see also Zeit. Phys. Chem., **87**, 257 (1914).

WOLSKI: Kolloidchemische Beihefte, **13**, 137 (1920).

(*b*) Quantitative measurements.

MARTIN: Proc. Roy. Soc. Canada, **7**, III., 219 (1913)—the first definite experimental evidence that liquids or indeed that any dust-free media scatter light.

R. J. STRUTT: Proc. Roy. Soc., **95A**, 155 (1919)—a measurement of the light scattered by liquid ether is given.

MARTIN: Jour. Phys. Chem., **24**, 478 (1920)—quantitative measurements of relative intensity.

MARTIN and LEHRMAN: Jour. Phys. Chem., **26**, 75 (1922); Proc. Roy. Soc. Canada, **15**, 50 (1921)—measurements of absolute intensity; two-component liquid mixtures.

KENRICK: Jour. Phys. Chem., **26**, 72 (1922)—note on Wolski's paper.

RAMAN: Nature, **109**, 75 (1922); Proc. Roy. Soc., **101A**, 64 (1922); Molecular Diffraction of Light. University of Calcutta (1922)—preliminary notes on some work now in progress.

C. *Solids.*

R. J. STRUTT: Proc. Roy. Soc., **95A**, 476 (1919)—light scattered by quartz crystals, calcite crystals and glass.

RAMAN: Nature, **109**, 42 (1922)—light scattered by quartz crystals. Ibid., **109**, 138 (1922)—light scattered by amorphous solids—glass in particular.

4. CRITICAL OPALESCENCE. That gases, and also two-component liquid solutions of critical composition, scatter a very large amount of light even at some distance above the critical temperature has been observed by many investigators.

A. *Experimental data.*

AVENARIUS: Pogg. Ann., **151**, 306 (1874).

GUTHRIE: Phil. Mag., (5) **18**, 504 (1884).

WESENDONCK: Zeit. Phys. Chem., **15**, 262 (1894).

ROTHMUND: Zeit. Phys. Chem., **26**, 433 (1898); **63**, 54 (1908). See this last paper for review of work on binary liquid mixtures.

FRIEDLÄNDER: Zeit. Phys. Chem., **38**, 385 (1901).

FÜCHTBAUER: Zeit. Phys. Chem., **48**, 552 (1904).

TRAVERS and USHER: Proc. Roy. Soc., **78A**, 247 (1906), republished in Zeit. Phys. Chem., **57**, 365 (1907)—best review of critical opalescence in gases.

YOUNG: Phil. Mag., (6) **20**, 793 (1910).

KAMERLINGH-ONNES and KEESOM: Comm. from the Phys. lab. at Leiden, No. 104b., republished in Amst. Proc., **10**, 611 (1908), also in Ann. der Phys., **35**, 591 (1911). In this paper the opalescence of ethylene has been measured at various temperatures above the critical temperature and for various wave-lengths of light. The results are in good accord with the Smoluchowski theory.

ANDANT: Comptes rendus, **174**, 1333 and 1541 (1922).

B. *Theories of critical opalescence.*

KONOWALOW: Ann. der Phys., **10**, 360 (1903).
DONNAN: Chem. News, **90**, 139 (1904).
SMOLUCHOWSKI: Ann. der Phys., **25**, 205 (1908).
KEESOM: Ibid., **35**, 591 (1911).
EINSTEIN: Ibid., **33**, 1275 (1910).
ORNSTEIN: Amst. Proc., **15**, 54 (1912); **17**, 793 (1914).

5. LIGHT-SCATTERING BY COLLOIDS.

Much work on light-scattering of both theoretical and experimental nature is to be found in the literature of colloidal chemistry. Rayleigh's theory has been much elaborated by Mie, Havelock, Garnet, Gans, Svedberg, Lorenz, Lorentz, J. J. Thomson and many others. Much experimental work has been done on both conducting and non-conducting particles of various sizes. For bibliography see:

BURTON: Physical properties of colloidal solutions—Longmans, Green (1921), pages 120-121.

6. THE BLUE COLOUR OF THE SKY and other meteorological and astronomical phenomena.

For bibliography see FOWLE: Jour. Opt. Soc. Amer., **6**, 105 (1922).

7. LIGHT ABSORPTION IN RELATION TO LIGHT-SCATTERING.

A. *Gases.*

KING: Phil. Trans., 212A, 375 (1913), abstracted in Proc. Roy. Soc., **88A**, 83 (1913)—Avogadro's number is deduced from measurements of atmospheric transparency. Review of theory of scattering in relation to atmospheric transparency. Nature, **93**, 557 (1914)—Rayleigh's law of extinction and the quantum hypothesis. Nature, **95**, 701 (1915)—speculation concerning the presence of gases in interstellar space. Proc. Roy. Soc. Canada, **8**, III., 59 (1914)—determination of Avogadro's number and the electronic charge.

FOWLE: Astrophysical Jour., **40**, 435 (1914), republished in Smith. Mis. Coll., **69**, No. 3 (1918)—Avogadro's number and atmospheric transparency. For further literature see Fowle's bibliography, paragraph 6 above.

B. *Liquids.*

(*a*) Measurements of absorption of water in the visible and ultra-violet.

HÜFNER and ALBRECHT: Wied. Ann., **42**, 10 (1891).
EWAN: Proc. Roy. Soc., **57**, 127 (1894).
ASCHKINASS: Wied. Ann., **55**, 401 (1895).
KREUSLER: Ann. der Phys. (4) **6**, 412 (1901).
AUFSESS: Ann. der Phys., (4) **13**, 678 (1904).
KAYSER: Handbuch der Spectroscopie, Vol. 3, 392—collection of the above data. Ewan's results are here misquoted, the base of the logarithm being confused. This error has been copied in other papers.

(*b*) Conclusions regarding scattering based on above absorption measurements.

FOWLE: Smith. Mis. Coll., **69**, No. 3 (1918).
RAMAN: Proc. Roy. Soc., **101A**, 64 (1922).

(*c*) The relation between light-absorption and light-scattering for liquids.

MARTIN: Jour. Phys. Chem., **26**, 471 (1922). In this paper the conclusions by Fowle and Raman are criticized, and some new measurements of absorption by dust-free water and benzene are given.

(*d*) The colour of water. There is need to distinguish carefully between colour of water by transmitted light—which is largely a question of selective absorption—and colour of water against a black background, in which case scattering by suspended impurities and molecular scattering are the important factors. See papers under 7 (*b*) above. For reviews of earlier work on colour of water see:

LORD RAYLEIGH: Roy. Inst. Proc., Feb., 1910; Nature **83**, 48 (1910); Collected works, Vol. 5, page 540.

BANCROFT: Jour. Frank. Inst., **187**, 249 and 459 (1919), republished in Chem. News, **118**, pages 197-200, etc. (1919).

8. SOME RECENT ARTICLES, largely theoretical, concerned with the development of the theory of light-scattering and the interpretation of the recent experimental results.

BORN: Deutsch. Phys. Gesell., **19**, 243 (1917); **20**, 16 (1918).
LORD RAYLEIGH: Phil. Mag., **36**, 429 (1918).
LARMOR: Phil. Mag. **37**, 161 (1919).
KUNZ: Phil. Mag., **39**, 416 (1920).
WOOD: Phil. Mag., **39**, 423 (1920).
SCHUSTER: Proc. Roy. Soc., **98A**, 248 (1920).
J. J. THOMSON: Phil. Mag., **40**, 393 (1920).
GANS: Ann. der Phys., **65**, 97 (1921).
BORN and GERLACH: Zeit. f. Phys., **5**, 374 (1921).
DOI: Phil. Mag., **43**, 829 (1922).
HAVELOCK: Proc. Roy. Soc., **101A**, 154 (1922).

Investigation of Dispersion by an Interference Method.

By H. F. DAWES, M.A., Ph.D.,
Professor of Physics, McMaster University, Toronto.

(Communicated by J. PATTERSON, Esq., M.A., F.R.S.C.)

(Read May Meeting, 1922)

Synopsis. The paper discusses the distribution of the Interference Fringes of an interferometer system for which the two paths are of unsymmetrical dispersion, for example, a Michelson interferometer in one path of which is inserted a plane parallel plate of dispersive substance such as glass. The spectrum of the interfering light with white illumination shows fringes in the form of a system of closed curves centering on the wave-length for which the number of wave-lengths in the difference of path is a maximum. These are illustrated by spectrograms with sunlight illumination. The numerical results give the dispersive power of the substance to a high degree of precision.

Introduction

1. Interference methods are specially suitable for the investigation of *dispersion* and are in common use for the measurement of the dispersion of a gas. Such methods may also be used to determine the dispersion constants of a substance in the form of a thin film or its equivalent as described, for example, in Mann's Manual of Advanced Optics, pages 35-39, 63, 64. The following paper presents an interferometer method of studying the dispersion of plane parallel plates of considerable thickness with the possibility of measuring the dispersive power to a high degree of precision. The index of refraction of a prism with accurately worked surfaces may be precisely determined by the Minimum Deviation method. Since, however, the dispersion depends on the differences of the indices in the second decimal place in numbers in the neighbourhood of 1.5 to 1.7 any residual error in the determination of the index by the above method becomes relatively some hundred times as important in the determination of the dispersion. The interferometer method, on the other hand, gives the value of the dispersive power with the same degree of precision as the single index used in reducing the observations. The

experiment is, moreover, extremely interesting in itself, involving a series of fine optical adjustments and giving some very beautiful results.

Experimental Arrangement

2. Fig. 1 shows the arrangement of apparatus. M is the movable mirror of a Michelson Interferometer. The interferometer is accu-

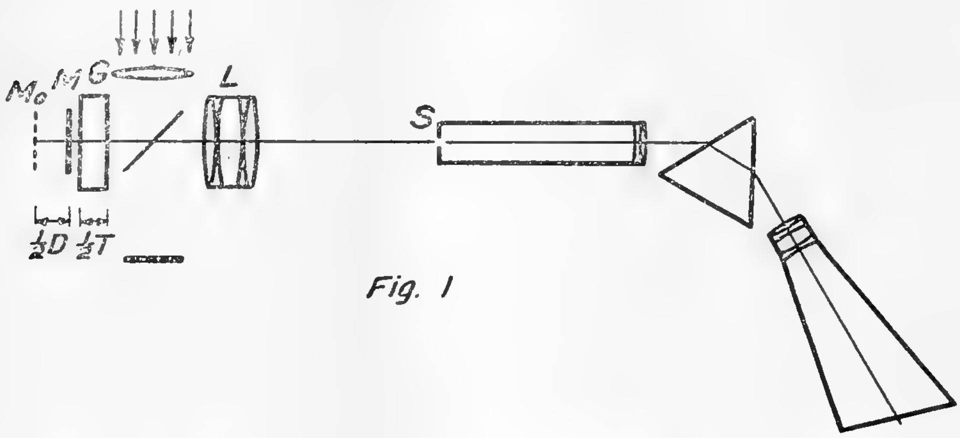


Fig. 1

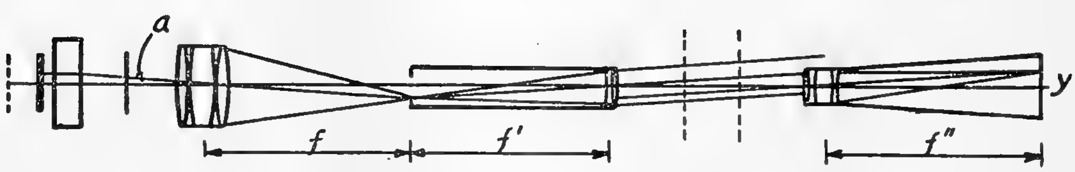


Fig. 2

rately adjusted for a parallel "equivalent thin film," as shown by circular fringes of apparent diameter independent of the position of the observer. The two interferometer paths are accurately equal when M occupies the position M_0. M has been drawn up a suitable distance, $D/2$ thereby introducing a difference of path D. The system is illuminated by sunlight slightly converged by a condenser lens so that the image of the sun will not be situated at the focal planes of the lenses subsequently traversed by the light.

G is the plane parallel glass plate of index μ whose dispersion is to be investigated; it is placed in the adjustable path of the interferometer parallel to the mirror M so that it is traversed normally by the rays normal to M. The index of refraction of G for the D_1 line as obtained by refractometer method is 1.57308 and the thickness of the plate is .9344 cm. (T/2).

With this arrangement there exists a difference of path between the two sets of interfering waves; the number of wave-lengths in this difference varies throughout the spectrum not only on account of the variation in the wave-length but also on account of the refraction and dispersion of the glass plate. Certain constituents of white light are destroyed by interference and others reinforced and, in general, there are present so many constituents so widely distributed throughout the spectrum that the light is white to the eye and there is no sign of interference. It is possible, however, with very thin plates to adjust D so that only sufficiently few constituents are present that coloured fringes may be observed. (See above reference.) In order to show the presence of interference fringes with thicker plates of glass one must use a spectroscope to analyse the light.

The fringe system is situated at infinite distance, the photographic objective L of focal length f produces an image of the system at its second focal plane, the image being a series of concentric superposed circles. S is the slit of a single prism spectrograph of which the focal lengths of collimator and camera lens are f' and f''. (Camera may be replaced by a telescope for visual observation.) The slit is at the focal plane of L so that the fringe system is focussed upon it. It is much longer than for ordinary use in order to produce a relatively wide spectrum. The condensing lens is so adjusted as to give illumination over the whole length of the slit. The spectroscope thus selects a narrow section of the fringe system at a vertical diameter of the set of circles and analyses it. The central longitudinal element of the spectrum corresponds to light traversing the interferometer system normal to the mirrors and the faces of the plate. Other longitudinal elements correspond to rays parallel to the vertical plane but inclined to the horizontal as indicated in Fig. 2, which is a vertical section of the system. Plates 1-8 show the character of the spectra observed

TABLE 1

Plate No.	D(cm.)	n_{D_1}	$n_{max.}$	λ x 10^8cm.	Dispersive Power
1	1.1377	1131.8	1143.4	6405	611.8
2	1.1627	1555.8	1556.8	5740	833.1
3	1.1877	1979.8	2012.4	5270	1076.8
4	1.2127	2403.8	2504.9	4915	1340.5
5	1.2377	2827.8	3028.9(5)	4627	1620.8
6	1.2627	3251.9	3583.4(5)	4400	1917.5
7	1.2877	3675 9	4163.8(5)	4216	2228.1
8	1.3127	4099.9	....	....	....

with various values of D in arithmetical progression as recorded in Table 1. Readings on the negatives were taken by an optical comparator graduated to 1/100 mm. and interpreted into wave-lengths by means of a calibration table. (Section 7.)

Theory and Results

3. Consider first the set of normal rays with the corresponding central element of the spectrum. By drawing up M the distance $D/2$ the number of wave-lengths in the adjustable path is decreased by D/λ for light of wave-length λ. If μ is the corresponding index of refraction of the glass plate its insertion introduces $(\mu-1)\ T/\lambda$ wave-lengths. Hence the number of wave-lengths in the difference of path is,

$$n=\{D-(\mu-1)T\}/\lambda \qquad (1)$$

For the constituents of the spectrum for which n is integral there is reinforcement, and in passing from one integer to the next the light intensity goes through a complete cycle of values. The spectrum is, therefore, crossed by a series of fringes for which, in general, the numbers of waves in the difference of the interferometer paths differ by unity for each pair of adjacent fringes. Equation (1) may, therefore, be taken to represent the distribution of these fringes throughout the spectrum, expressing n as a function of λ, remembering that μ is also a function of λ.

Assuming the value of μ for the D_1 line the number of D_1 wave-lengths for the value of D corresponding to Plate 1 is 1131.8 and for the other plates the values of n_{D_1} are shown in Table 1. With these values as starting points one may pass up and down the spectrum and assign the value of n to each fringe. The values of n increase from both directions toward a centre, the values being equal for equal counts on either side of that centre. Each negative shows several hundred fringes, and Table 2 contains an illustrative selection from

TABLE 2

n	Scale Reading	Wave-length x 10^8 cm.	Scale Reading	Wave-length x 10^8 cm.
2270	9.47	4007	.....	....
2300	12.28	4050	.....	....
2350	17.61	4141	.....	....
2377	.....	....	65.84	6063
2400	23.48	4253	64.22	5925
2403.8	.....	....	63.91	5896
2450	30.48	4405	59.76	5596
2500	41.92	4742	50.78	5098
2502	42.93	4777	49.85	5055
2503	43.58	4801	49.27	5029
2503.5	43.98	4815	48.96	5015
2504	44.42	4832	48.57	4999
2504.5	45.03	4855	48.07	4977
2504.9(n_{max})	.....	4915	.....	4915

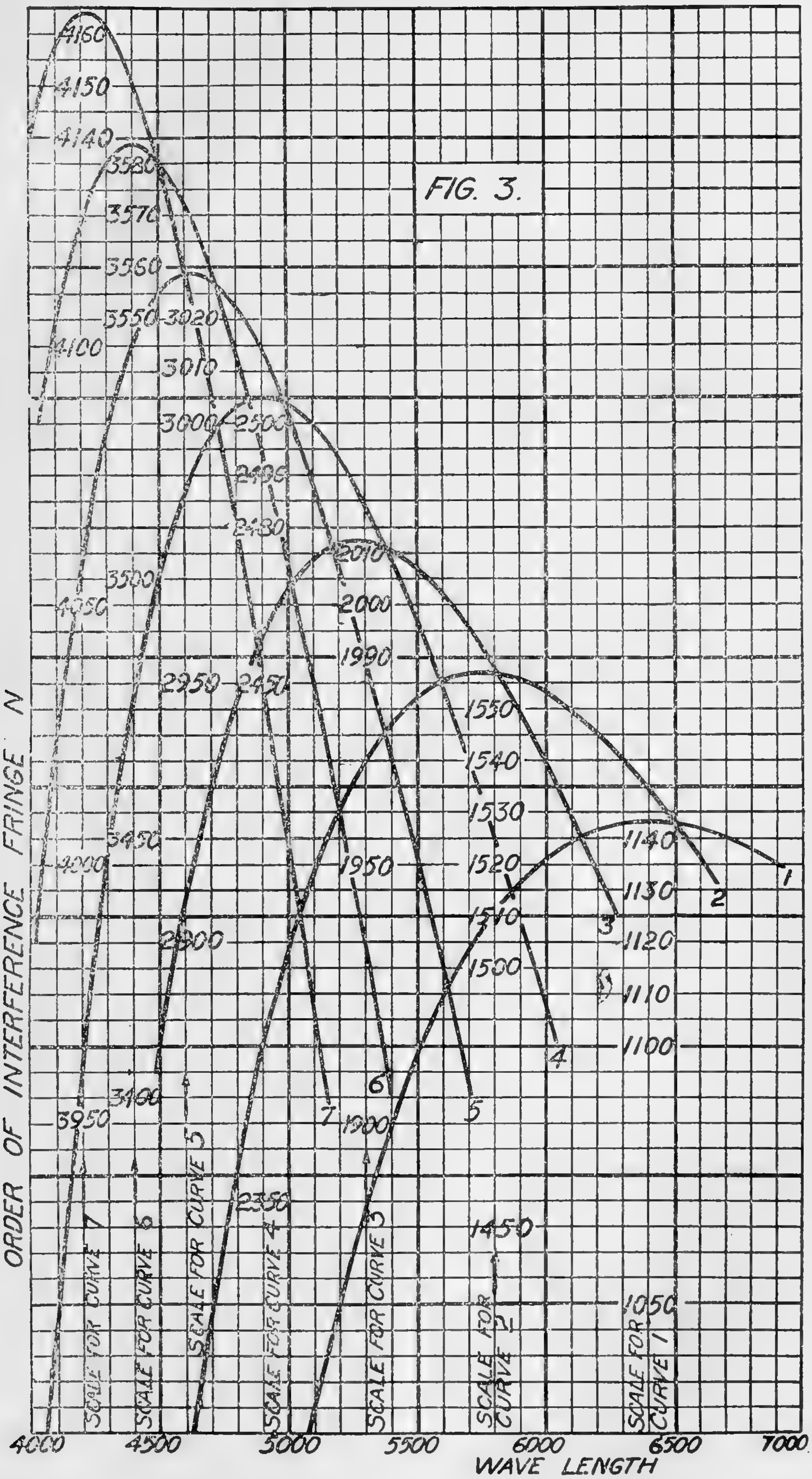

ORDER OF INTERFERENCE FRINGE N
WAVE LENGTH
4000
4500
5000
5500
6000
6500
7000
SCALE FOR CURVE 7
SCALE FOR CURVE 6
SCALE FOR CURVE 5
SCALE FOR CURVE 4
SCALE FOR CURVE 3
SCALE FOR CURVE 2
SCALE FOR CURVE 1
1
2
3
4
5
6
7

FIG. 3.

the set of readings belonging to Plate 4. The first decimal place in the wave-length values might quite properly have been calculated and shown, but it did not seem requisite for the purpose of the present paper.

Fig. 3 illustrates the relation between n and λ by curves, one for each plate, and shows the range of values for n corresponding to the selected values of D, as well as for the different wave-lengths of the spectrum. On account of the great range of values of n each curve is drawn with a separate calibration on the n axis, the values being marked for each beneath the corresponding peak. It will be seen that there is a very large number of observations available for plotting each of these curves. (See also Section 5.)

4. Solving (1) gives $\mu = 1 + D/T - n\ \lambda/T$, from which values of μ may be calculated with a high degree of precision since the major part $1 + D/T$ is independent of the variable. For Plate 4, for example, the numerical formula is $\mu = 1.648919 - .5351\ n\ \lambda$.

The relation between the indices at the various parts of the spectrum may also be expressed in somewhat different form. If n' is the order of the interference fringe at the wave-length λ' and μ' the index, then

$$\mu' = 1 + D/T - n'\ \lambda'/T.$$

Hence $\mu' = \mu + (n\ \lambda - n'\ \lambda')/T$, by which the index at wave-length λ' may be calculated from the index at wave-length λ. n' is determined by adding to n the number of fringes by which λ is more remote than λ' from the central point of the system.

If the fringes at λ and λ' are of the same order n, being on opposite sides of the centre, then

$$\mu' = \mu + (\lambda - \lambda')\ n/T.$$

5. In (1) n may be a maximum corresponding to the wave-length in the spectrum for which the fringes are most widely separated. The condition for this gives

$$-\frac{d\mu}{d\lambda} = \frac{n_{max}}{T} \qquad (2)$$

i.e., a formula for the dispersive power at the wave-length λ of the central point of the fringe system. Both factors, n_{max} and T, may be determined to a high degree of precision, the relative accuracy increasing with the thickness of the specimen. It is true that n_{max} must be determined by interpolation, but it lies within .25 of a direct reading in a number which is upwards of one thousand so that even without closer estimation the error cannot be greater than one part in four thousand. The value of λ corresponding to the maximum

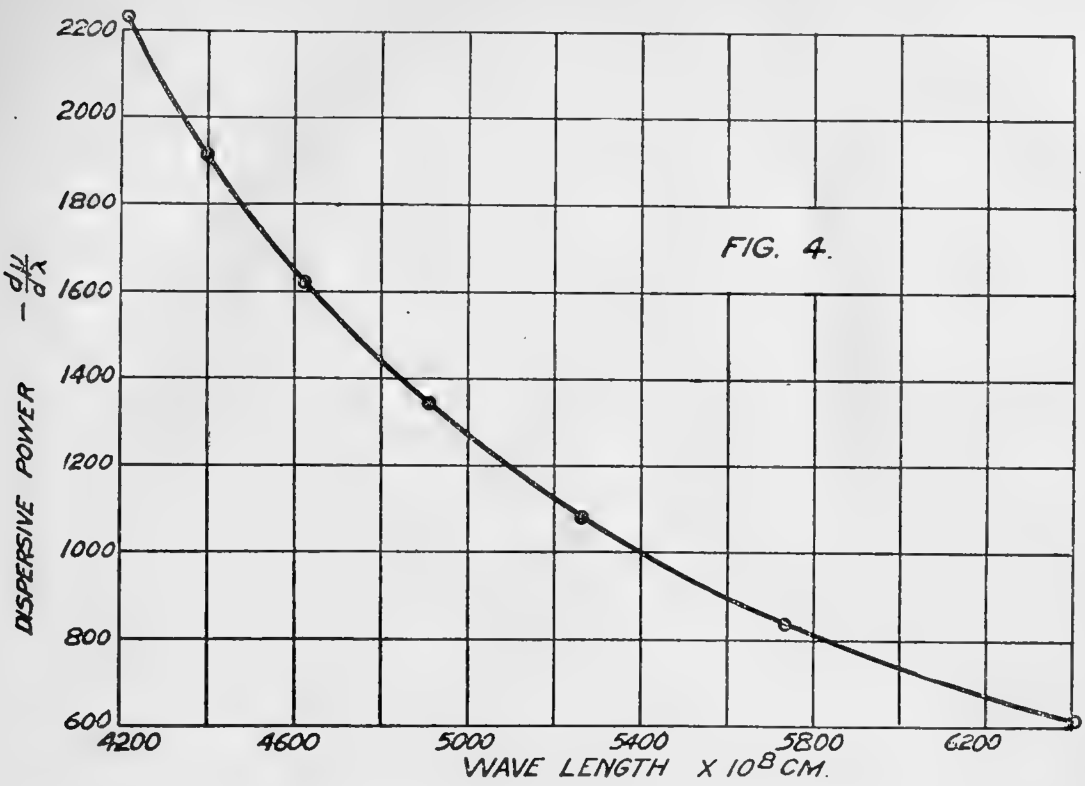


FIG. 4.
DISPERSIVE POWER $-\frac{d\mu}{d\lambda}$
2200
2000
1800
1600
1400
1200
1000
800
600
4200
4600
5000
5400
5800
6200
WAVE LENGTH X 10^8 CM.

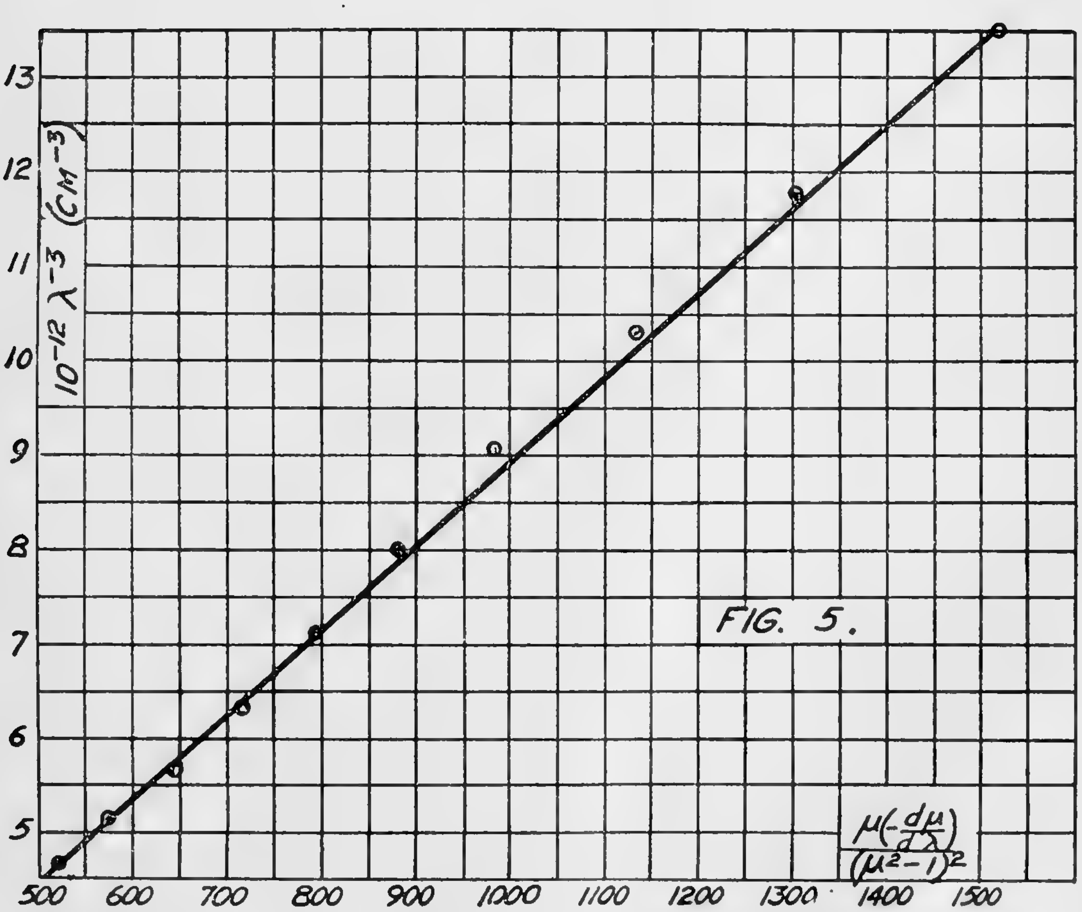


FIG. 5.
$10^{-12}\lambda^{-3}$ (CM^{-3})
13
12
11
10
9
8
7
6
5
500
600
700
800
900
1000
1100
1200
1300
1400
1500
$\frac{\mu(-\frac{d\mu}{d\lambda})}{(\mu^2-1)^2}$

point may also be found by interpolation with precision using the standard method of finding the abscissa corresponding to a maximum ordinate.

The curves of Fig. 3 show these maximum positions. It will be seen that as D increases the maximum point moves downward toward the spectral region of shorter wave-length and there are very great changes in the value of n_{max}. In fact, on Fig. 3 the maximum points actually plot out a curve showing the relation between the dispersive power and the wave-length since the ordinates of these points are proportional to the powers. In Table 1 are shown the values or the maximum orders corresponding to the various plates, together with the corresponding wave-lengths and dispersive powers, and the relation between the last two are illustrated by Fig. 4.

6. The values of the dispersive powers permit a test of the applicability of the various dispersion formulæ. Assuming that the principal absorption line of the glass is in the extreme ultra-violet the Lorentz-Lorenz dispersion formula may be written

$$\frac{\mu^2+2}{\mu^2-1}=\frac{1}{A}\left(1-\frac{\lambda_1^2}{\lambda^2}\right)$$

Differentiating in order to introduce the *dispersive power* in which this paper is particularly interested,

$$-\mu\frac{d\mu}{d\lambda}/(\mu^2-1)^2=\frac{\lambda_1}{3A}/\lambda^3$$

Hence one may test out the formula in terms of the numerical values shown by plotting

$$-\mu\frac{d\mu}{d\lambda}/(\mu^2-1)^2 \text{ against } 1/\lambda^3$$

with the expectation of obtaining a straight line. This curve is plotted in Fig. 5 and shows a slight but definite deviation from the rectilinear.

7. Consider rays traversing the interference system parallel to the vertical plane but making a small angle a with the mirror normals. From Fig. 2 it may be seen that such rays are focussed at a point on the spectrum distant $a\,f\,f''/f'$ from the central element so that this is the y co-ordinate of such point referred to the central element as axis. λ is a function of the x co-ordinate which may conveniently be written X. Let us examine the distribution of the interference fringes in the plane of the spectrogram.

For the rays above specified the difference of path introduced on account of the distance $D/2$ is $D\cos a/\lambda$ wave-lengths and on account of the insertion of the glass plate $T\sin(a-b)/\lambda\sin b$.

Hence $$n_a = \frac{D\cos a}{\lambda} - \frac{T}{\lambda}\frac{\sin(a-b)}{\sin b}$$

Since a, b, are small and $\sin a = \mu \sin b$ the value of n_a approximates to

$$\frac{D-T(\mu-1)}{\lambda} - \frac{a^2}{2\lambda}\left\{D+T\left(1-\frac{1}{\mu}\right)\right\}$$

$$\text{or} \quad n_a = n_o - \frac{a^2}{2\lambda}\left\{D+T\left(1-\frac{1}{\mu}\right)\right\} \qquad (3)$$

Hence $$\lambda n_a = D - T(\mu-1) - \left(\frac{f'y}{ff''}\right)^2 \frac{1}{2}\left\{D+T\left(1-\frac{1}{\mu}\right)\right\}$$

expresses the relation between y and the wave-length for any selected value of n_a

and $$Xn_a = D - T(\mu-1) - \left(\frac{f'y}{ff''}\right)^2 \frac{1}{2}\left\{D+T\left(1-\frac{1}{\mu}\right)\right\}$$

the relation between x and y.

(3) shows that n_a diminishes as a increases at any selected wave-length so that, as regards the partial variation of n with y, n is a maximum when y is zero, the central point of the fringe system is, therefore, a maximum for variations in both λ and y. The locus of the fringe of any order n is a closed curve and the fringe system forms a family of curves enclosing the central point. The photographs show only a few complete curves, but if the spectrum were sufficiently widened the complete system might be shown.

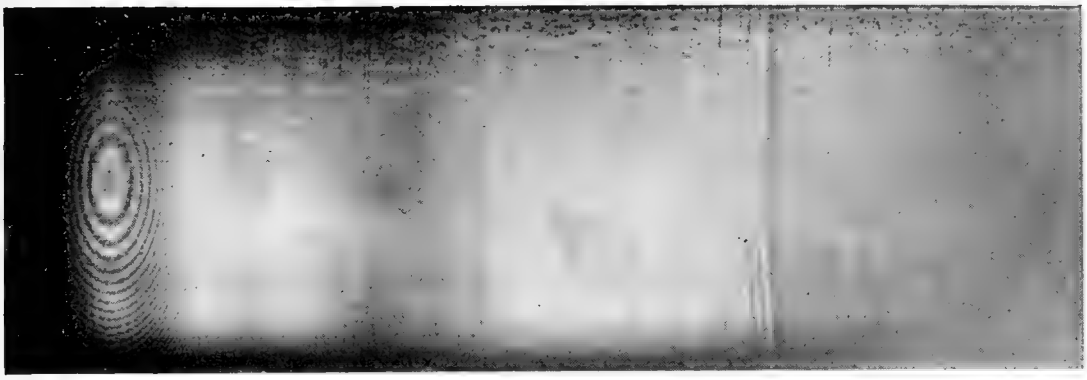
Calibration of Spectrograph

8. The arrangement may be readily adapted to calibrate the spectrograph, forming, in fact, a modification of the well-known method of Edser and Butler. If the plate G is removed the spectrograph slit will be illuminated by light in which successive constituents are interference maxima and minima. The number of wave-lengths in the difference of path becomes simply D/λ. The spectrum will show a series of fringes of orders $n+1$, $n+2$, . . . from λ toward the violet end and $n-1$, $n-2$, . . . toward the red end. The wave-length at each such fringe is, therefore, obtained by dividing D by the number of the corresponding order.

Plate 9 shows a spectragram used for calibration. For it D is .03770 cm. and n for the D_1 line 639.3. The total number of fringes measurable on the negative is 319 so that this negative yields a very close calibration. From the comparator readings a large scale calibration curve was plotted and thence a table constructed, giving the wave-length for each .1 of the comparator scale with differences for the second decimal place. The dispersion of the spectragraph was such as to require about .05 at the violet end and .01 at the red end for one Angstrom unit.

McMaster University,
Toronto, Canada.
May 1, 1922.

1



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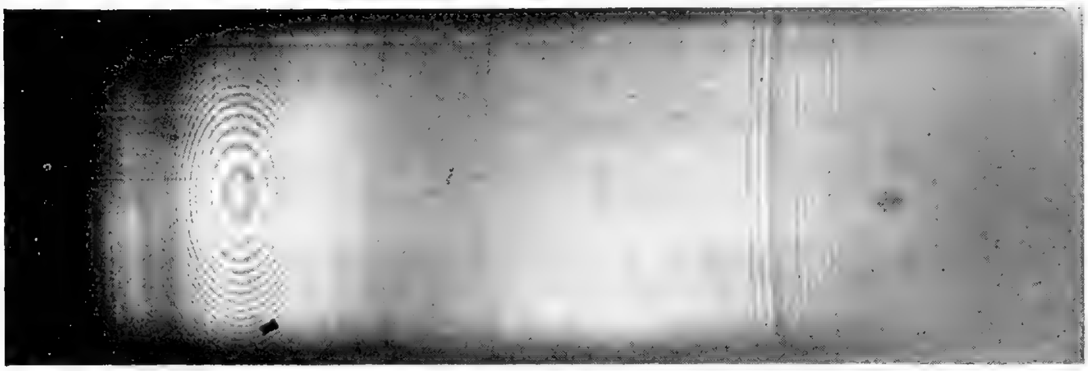

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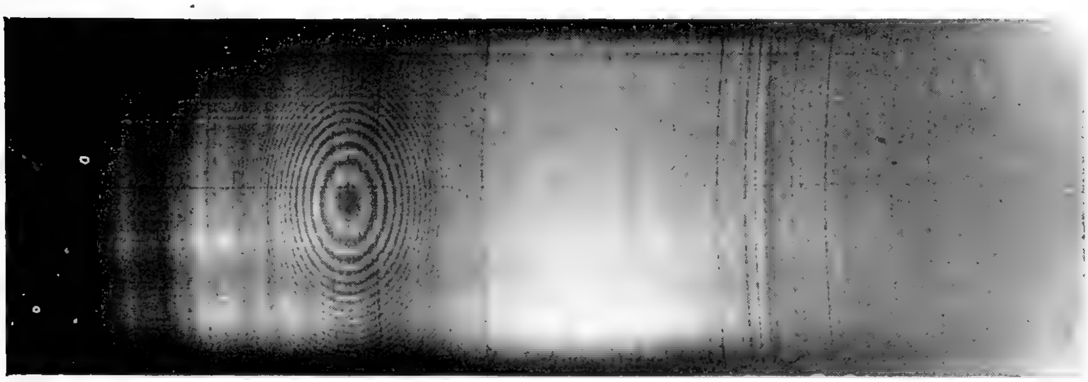

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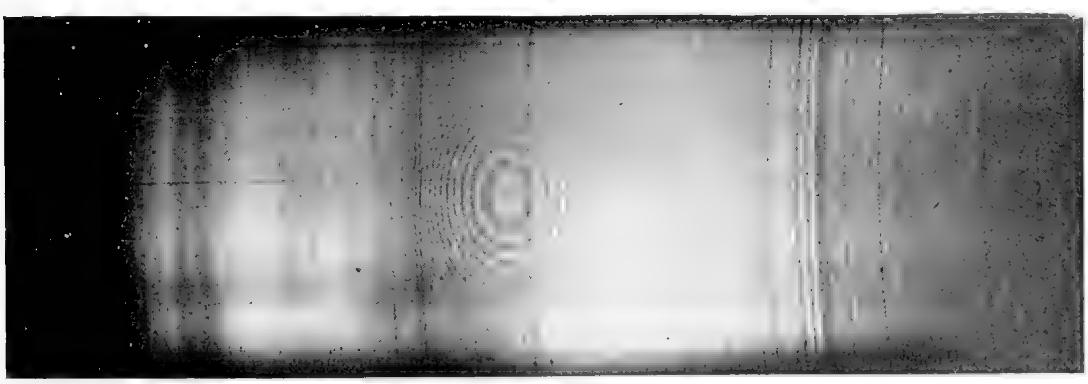
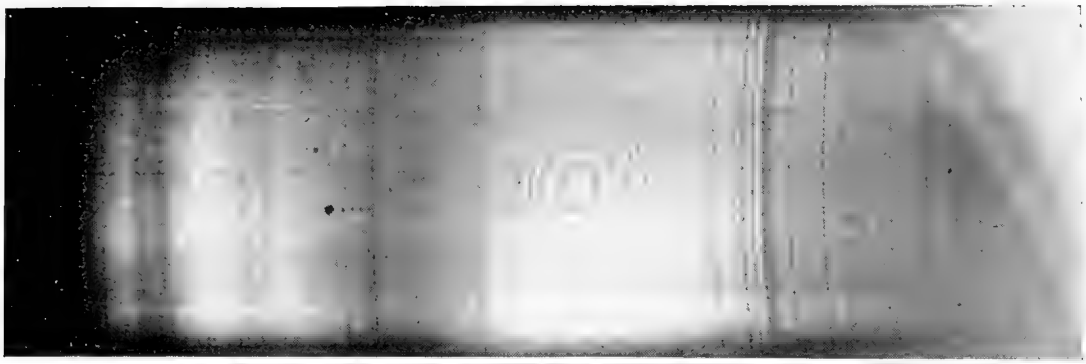


PLATES 1—4

5



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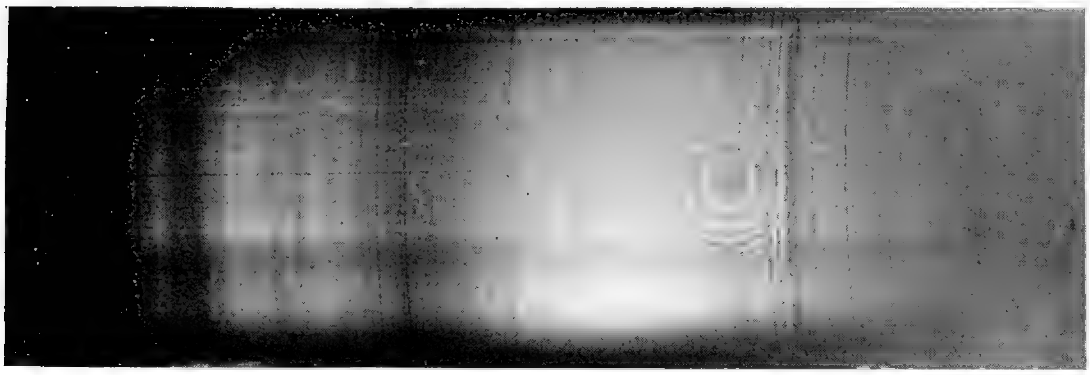

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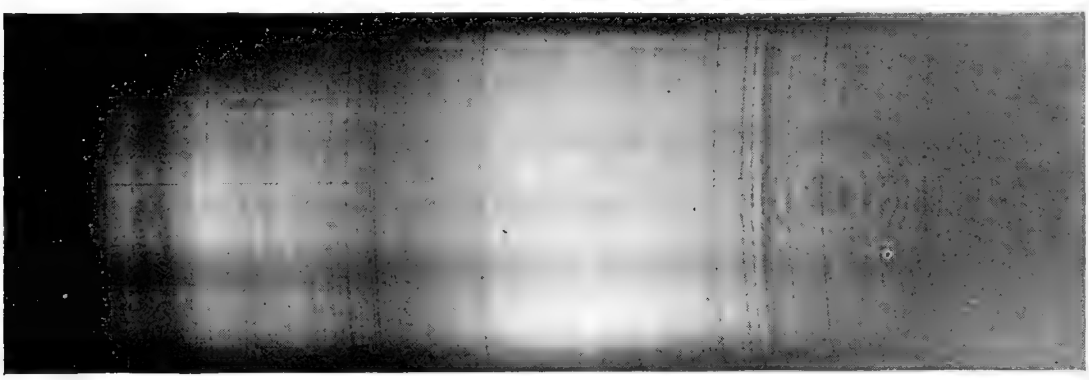

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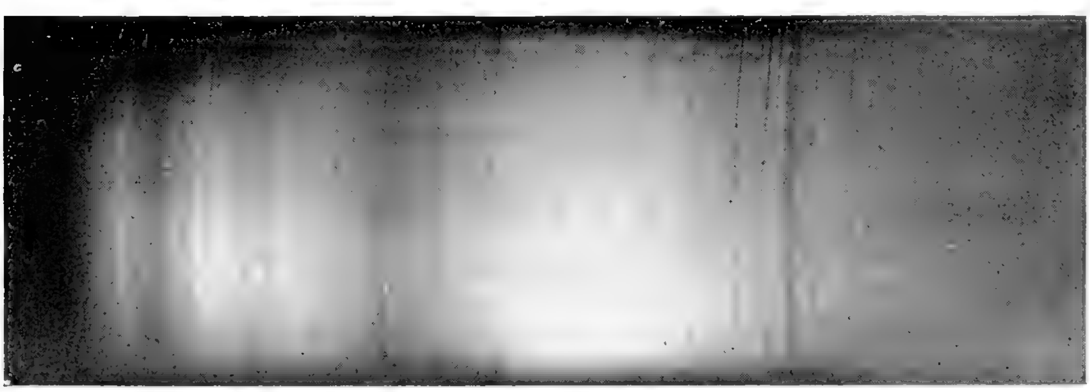


PLATES 5—8

PLATE 9

Compressional Waves in Metals Produced by Impact

By R. W. BOYLE

(Read May Meeting, 1922)

I. *Duration of the Impact*

In the older compressional wave theory of impact it was considered that when two bodies impinged on one another the compression produced at the surface of contact gave rise to compressional waves, which travelled through the length of both bodies during the first half of the impact, were reflected back from the far ends as waves of tension, and then on return thrust the bodies apart.

A result of the theory would be that the duration of the impact is comparable with the gravest period of free vibration in the bodies, and this result is contradictory to experiment.

A very different theory is that given by Hertz,[1] where all relations involving possible vibrations set up in the bodies are disregarded, and the compression at the junction is treated as a purely local effect in which the pressure gradually rises until the bodies are brought to rest and then subsides until they are separated. A necessary consequence is that the duration of impact should be a large multiple of the gravest period of free vibration in either of the impinging bodies; also the duration of the impact should vary inversely as the fifth root of the relative velocity of approach of the bodies before impact. Hertz himself obtained some evidence in confirmation of his theory, in that the linear dimensions of the compressed area at contact was shown to be proportional to the cube root of the pressure between the bodies; and quite recently Tschudi[2] has reported the results of a series of exact experiments on colliding spheres and bars, in which he finds, concerning the duration of impact, that in all cases the measured duration was much greater than the values expected on any theory of compressional waves. For example, taking the case of a moving bar of steel, 31.3 cms. long and 2.86 cms. in diameter, impinging on the end of a similar bar at rest, the duration of impact was shown to depend on the relative velocity of approach, agreeing fairly well with Hertz' law. In the case of an approaching velocity of 50 cms. per second, the duration of impact was 3×10^{-4} seconds, whereas on the compressional wave theory it would be 1.2×10^{-5} seconds for any approaching velocity.

[1]Love's Mathematical Theory of Elasticity, 2nd ed., 1906, p. 195.

[2]Physical Review, vol. xviii, Dec., 1921.

Tschudi, following the method of Hertz, has developed a mathematical formula, involving two empirical constants which he determined in his experiments, giving the relation between the duration of impact, velocity of approach, and length of colliding bars, in the case of two circular section bars impinging end on.

The considerations just mentioned have a bearing on the method of exciting longitudinal waves in a metal bar, as described in the paper by Mr. Lang[1] at this meeting. The waves there are excited by the impact of a hammer on the end of a metal bar clamped in the middle, and some of the energy of the impact is transformed into compressional waves, for their existence is easily demonstrated by the "Kundt's figures" which can be produced in a tube at the far end of the bar. Tschudi's formula will not exactly apply here, where the bar at rest was clamped and not free, but it at least will indicate the order of the time required for the duration of the impact.

The gravest note produced by the compression will be that in the clamped bar and the time of travel of this wave forward and back along the bar can be calculated from the measurement of the length of the Kundt's figures so produced or from the length of the bar. This period, on Hertz' theory of impact, should be much less than the duration of the impact, the order of which we can now calculate, accepting Tschudi's results and extrapolating in his formula.

Taking the cases of the longest and shortest bars of steel experimented with by Mr. Lang, giving high frequency longitudinal waves on impact of 1,280 to 50,000 vibrations per second, the diameter of the bars being 2.54 cms., and the velocity of approach 100 cms. per second, we have the following:

Length of clamped bar	Length of hammer	Period of vibration	Calculated duration of report
200 cms.	3 cms.	7.8×10^{-4} secs.	9×10^{-4} secs.
5 "	3 "	2×10^{-5} "	9×10^{-5} "

It is seen that for both longest and shortest bars and very short hammer the time for the duration of impact was greater than the period of longitudinal vibration, though the two are approaching the same value as the period of oscillation lengthens. It follows that the thrust to separate hammer and bar by waves reflected from the far end of the bar must always be less than the pressure created by the impact until the latter disappears; and it follows also that the longitudinal waves can travel back and forth in each bar, and be

[1]R. J. Lang, High Frequency Vibrations and Elastic Modulus of Metal Bars. Trans. Roy. Soc. Can., May, 1922.

reflected at the common junction of the two, while the bars are actually in contact. This is quite contrary to the compressional wave theory.

II. *Damping of the Longitudinal Waves*

The impact of the hammer on the clamped bar excites by "shock" longitudinal waves of period corresponding to that of "free" vibration of the bar. The length of the bar being one-half the wave-length of the fundamental note of the bar.

There is a question as to how sustained this vibration will be. The damping of the vibration is due to the energy dissipation by the "viscous" resistance of the solid material of the bar, and will depend on the value of the coefficient of "solid viscosity." When the emitted note is of audible pitch it is possible to determine qualitatively by the ear that in the materials steel, brass, dur-aluminium, the vibrations persist for an appreciable time.

The differential equation of the vibrating motion in the bar, considering the wave travel is that of plane waves, and neglecting all energy dissipation by lateral motions, is

$$\frac{d^2y}{dt^2} - \frac{E}{\rho}\cdot\frac{d^2y}{dx^2} - C\frac{d^3y}{dx^2dt} = O$$

where y is the displacement, E Young's modulus, ρ the density, and C a constant depending on the material and including the coefficient of viscosity.[3]

It should be noticed that by using Young's modulus we are not entirely neglecting all account of lateral motion, since in any determination of E lateral motion always is possible and takes place. Further the experiments of Mr. Lang show that lateral motion, even to frequencies of 50,000 vibrations per second, has less effect than might have been expected on the velocity of the longitudinal waves in the rod, and therefore on the dissipation of energy.

From the solution of the equation above, the expression for the velocity of the waves is

$$V^2 = \frac{E}{\rho} - \frac{C^2k^2}{4}$$

where $k = \frac{2\pi}{\lambda}$, λ being the wave-length and in the present instance twice the length of the bar. The damping constant, i.e., damping with regard to time, is $\frac{Ck^2}{2}$. It is possible, and even likely, that C will

[3]Rayleigh, Theory of Sound, Vol. II, para. 346.

not be independent of the frequency; but here, in order merely to get an idea of the order of its effect, we shall assume that C is a constant of the material, the frictional dissipating force being strictly proportional to the rate of deformation. Also, theoretically, C may be taken as equal to $\frac{4\mu}{3\rho}$, where μ is the actual coefficient of viscosity in C.G.S. units, without departing from the correct order in our calculations.[4]

Unfortunately we have no value of the coefficient of viscosity, μ, that can be quoted to evaluate this damping constant, though experiments now in progress may be able to disclose its value at least approximately. Recently Ronda and Konno[5] have experimented on the determination of the coefficient of normal viscosity of metals, and find the normal and the tangential viscosity to be of the same order. The normal and tangential viscosities correspond, respectively, in elasticity to the *modulus of elasticity* and the modulus of rigidity; and hence it is the normal viscosity which is acting when a solid bar or rod vibrates longitudinally. But such vibrations in the case of metals are too rapid and too small in amplitude for experiments by a method such as was used by Honda and Konno. Accordingly the measurements to find the normal viscosity were made indirectly on larger and less rapid, flexural, vibrations, with period about 0.7 per second, and amplitude 5 to 25 mms. of maximum flexure on a length of 26 cms. The results show that the logarithmic decrement of these flexural vibrations, and therefore presumably also that of the accompanying longitudinal vibrations, *decreases linearly* with *decreasing amplitude* of oscillation, and for metals are of the order 0.7 to 27×10^8 in C.G.S. units. In the case of steel the coefficient of viscosity increases with the content of carbon and has an average value of 4×10^8 (about).

Although these values of normal viscosity correspond to the longitudinal vibrations of a rod—produced by flexure—the order is altogether too high to apply to plane longitudinal waves through the body of a bar without flexure, as in the case of a metal bar struck with a hammer.

A calculation from the theoretical formula for the velocity of longitudinal waves in the struck bar, viz.:

$$V^2 = \frac{E}{\rho} - \left(\frac{4}{3}\frac{\mu}{\rho}\right)^2 \frac{k^2}{4}$$

will make this clear.

[4]Rayleigh, loc. cit.

[5]Phil. Mag., Vol. 42, July, 1921.

Taking the case of steel, and a frequency of 40,000 vibrations per second, $k^2 = \frac{2\pi}{\lambda} = 0.5$ (about), $E = 2.14 \times 10^{12}$, $\rho = 7.85$. If the velocity is diminished by viscosity by as much as 5 per cent., which Mr. Lang's experiments show, is probably an excessive estimate, μ works out at a value of about 4×10^6 in C.G.S. units, instead of an order of 10^8 as in the experiments quoted.

With this value of coefficient of viscosity the damping constant would be, at a frequency of 40,000 vibrations per second, 4.2×10^4. Hence the damping factor would be $e^{-4.2 \times 10^4 t}$, and the time for the vibration to be damped to $\frac{1}{e}$, i.e., about 1/3 of its initial value, would be 2.4×10^{-3} secs. The vibrations are certainly more sustained than this, and therefore the coefficient of viscosity lower still than the value taken in this example. It is probable that the order of the coefficient of viscosity, when determined, will not be greater than 10^5.

Although no numerical values for the viscosity in metals can as yet be quoted it is possible, at least qualitatively, to get some idea of how sustained the vibrations are by the following experiment. The waves excited in the clamped rod can be detected by a microphone, provided the microphone is connected into a "tuned" electric circuit, and the received effect is made to produce a heterodyne "beat" note with the continuous electric oscillations from an ionic valve. The high frequency detected oscillations, or this "beat" note, or both, can be amplified, and the resulting tone made plainly audible by an ionic valve amplifier. In such a method it is best to put the waves from the rod into a liquid, like water or oil, and detect them with the microphone in the liquid, though the damping in this case will be increased by greater radiation from the rod than when the rod was emitting its note in air.

The experiment in the present case was performed as follows:

High frequency vibrations were produced in metal rods one inch diameter, and of lengths varying from 50 to 6 cms. The rods were clamped at the centre, the clamp being provided with a handle which could be held in the hand. The rod was hit at one end with a light hammer two cms. long, its other end being dipped into water or oil contained in a small box. A small water-tight microphone, affected, no doubt, only by the *pressure* of the sound waves in changing its electrical resistance, was employed, and is illustrated in figure 1. It consisted of two steel discs, each one cm. in diameter, and one mm. thick, with heavy rims, about 0.3 cms. wide and 0.3 cms. thick.

The rims, separated from one another by thin mica rings, were drawn closely together by screwing the top rim to the lower with fine screws through insulating ebonite bushings. In this way the steel discs were electrically separated from one another, and the whole enclosed a small water-tight space. On the insides of the discs, attached at the centre of each, were thin, carbon, microphone buttons, about 0.3 cms. in diameter, between which were packed the fine, spherical carbon granules of the microphone; the rest of the space inside was filled with a soft felt pad holding in the granules of the microphone. No doubt any microphone, acting by the pressure variations of sound waves, could also do, but there is an advantage in a microphone of the type here used; for the small, stiff, steel discs have a natural period corresponding to a high, inaudible note, and therefore the microphone has sensitivity in the upper ranges of frequency, while it tends to shut out the effect of ordinary low pitched sounds.

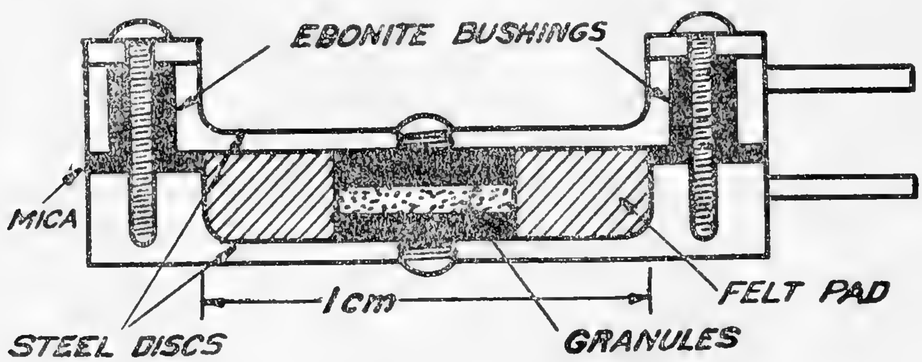


FIG. 1.

The microphone was connected into an electric battery circuit containing the adjustable primary of an oscillation transformer. The secondary, L, of this adjustably coupled transformer, with a variable condenser, C, was arranged in an ionic-valve circuit to give heterodyne "beat" reception; and the "beat" note was amplified by a three-valve, audio-frequency, amplifier. This accompanying diagram, Fig. 2, shows the electrical arrangements.

The high frequency waves produced by the struck metal rods could be picked up almost anywhere in the liquid by this microphone. The oscillations in the rods were found to be so sustained that the electric oscillations, transformed from them, in the electric circuit beat with the continuous electric oscillations from the ionic valves, and the beat note was distinctly heard in the amplifier telephones. The beat note could be varied in pitch in the usual way by varying the adjustable capacity C, and the two gamuts of beat notes—one on each side of the null point or point of unison—were present. In

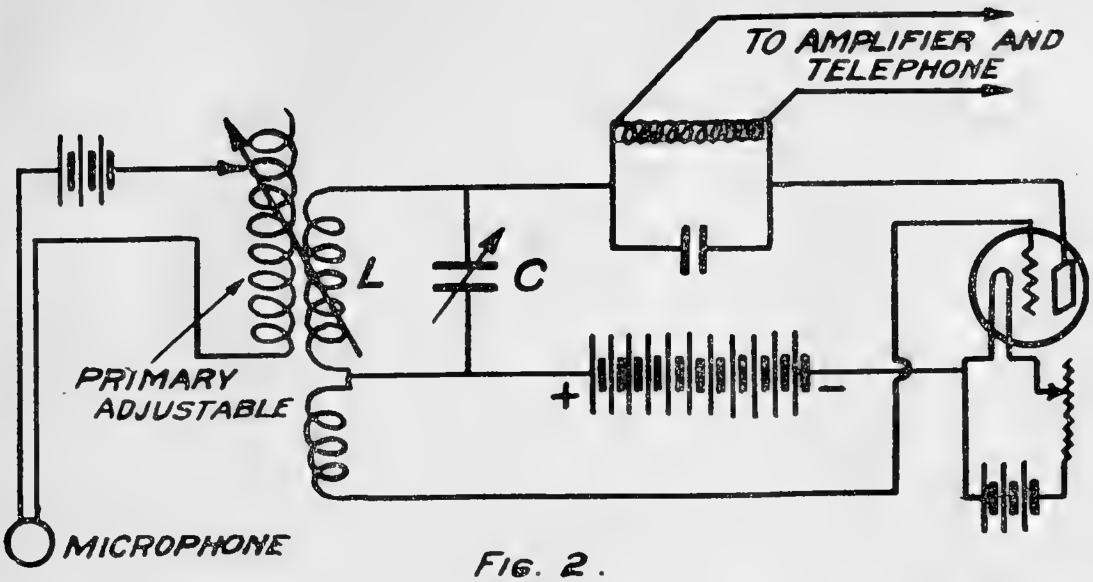


FIG. 2.

fact by having the capacity C accurately calibrated as a Hertzian wave-meter, the pitch of the note from the rod could easily be ascertained. This was the case in the experiments.

It was found that when the note emitted by the rod was of audible pitch, e.g., of 10,000 or 15,000 vibrations per second, both this fundamental note and the beat note could be heard in the telephones, but when the emitted note was above the limit of audibility, above 20,000 vibrations per second (about), the beat note only could be heard.

In this way the beat could be detected with a frequency of emitted note up to about 42,000 vibrations per second, i.e., from a rod six cms. long. Above this frequency no beat could be heard. Hence the train of waves for each blow of the hammer on the clamped bar was sustained enough, even at this high frequency, to give detectable beats with a continuous source.

The arrangement can be used as a simple method of finding the elastic modulus (E) of a bar of metal. For, finding the pitch (n) of the note emitted by the struck rod as just described, and the length of the rod (l) being half a wave-length, we have the relation

$$V = \sqrt{\frac{E}{\rho}} = n.2l$$

$$\therefore E = \rho(2ln)^2.$$

where ρ is the density of the material.

It is hoped to develop the experiment further.

Liquid Chlorine as an Ionizing Solvent

By J. MENNIE and D. McINTOSH

(Read May Meeting, 1922)

In the course of an investigation of some of the physical properties of liquid chlorine, Johnson and McIntosh[1] examined it as a solvent and failed to find any inorganic substance which conducted when dissolved in it. They observed that solutions of certain organic compounds containing oxygen, such as alcohols, ethers, ketones and esters, which themselves gave no evidence of ionization, began to conduct when a small quantity of HCl was added.

These substances, when dissolved in chlorine, form compounds of the general type A_xCl_y,[2] which are apparently not ionized. Plotnikov[3] found that ether dissolved in bromine gave a conducting solution but this was probably due to the formation of small amounts of HBr.[4] With the halogen acids compounds of the type $Ether_xHCl_y$[5] are formed and these conduct well.[6] Transport number determinations have shown that the ether is carried to the cathode, indicating that it forms part of a positively charged ion.[7] Johnson and McIntosh concluded that the conductivity which they observed was due to the ionization of these compounds.

The present investigation consists of a repetition of Johnson and McIntosh's qualitative tests and a quantitative study of the change in conductivity of solutions of the Ether-Chlorine type with addition of HCl.

Qualitative Results

Conductivities were measured by the Kohlrausch method, using a slide-wire bridge of the ordinary type. The conductivity cell was a small glass tube with sealed-in electrodes. About 4-6 ccs. of chlorine was used. The cell was kept in a bath of ether and solid

[1]Jour. Am. Chem. Soc. 31: 1138 (1909).

[2]D. McIntosh, Jour. Chem. Soc. 87: 784 (1905); Jour. Am. Chem. Soc. 33: 71 (1911).

[3]Zeit. Phys. Chem. 4: 502 (1906).

[4]Johnson and McIntosh, loc. cit., p. 1144.

[5]Archibald and McIntosh, Jour. Chem. Soc. 85: 919 (1904).

[6]Steele, McIntosh and Archibald, Phil. Trans. A-205: 99 (1905); Archibald, Jour. Am. Chem. Soc. 29: 665 (1907); Maass and McIntosh, Jour. Am. Chem. Soc. 35: 535 (1913).

[7]Steele, McIntosh and Archibald, loc. cit.

carbon dioxide, which gives a fairly constant temperature of $-78°C$. The chlorine was made by dropping hydrochloric acid on potassium permanganate, was passed through wash-bottles containing water and concentrated sulphuric acid and was dried with phosphorus pentoxide. The mean of a number of measurements gave a value of 0.07×10^{-6} for its conductivity, but with the apparatus at our disposal it was impossible to determine the minimum point with any degree of accuracy.

Tests were made with about 180 inorganic compounds, including various salts of all the common metals, and such substances as water, hydrogen chloride, hydrogen sulphide, tin tetrachloride, bromine, etc. About 80 organic compounds were also tested, including hydrocarbons, alcohols, ketones, aldehydes, esters, acids, amines, nitriles, etc. In no case was evidence of ionization obtained.

Hydrochloric acid, generated by the action of sulphuric acid on sodium chloride and dried with phosphorus pentoxide, was then bubbled through solutions of pentane, acetic acid, aldehyde, ethylamine, ether, alcohol, ethyl acetate and acetone in chlorine. The first four showed no evidence of ionization, but the last four gave conducting solutions.

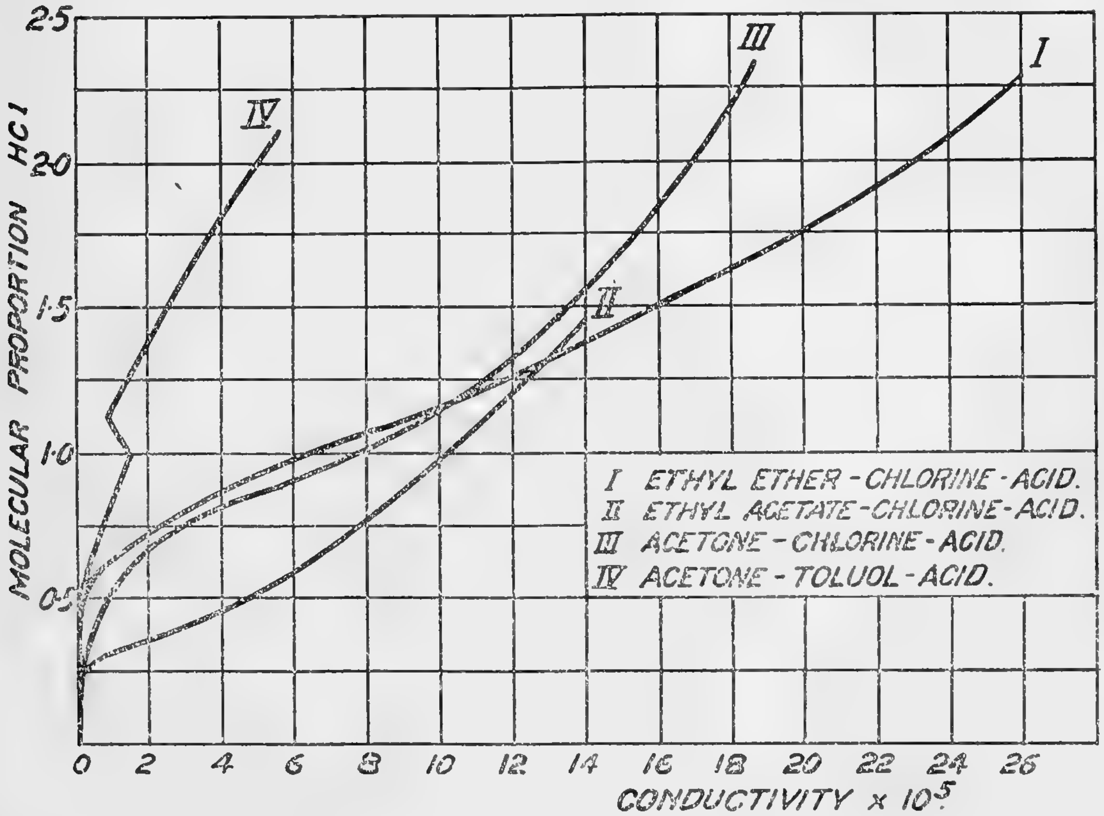
Quantitative Measurements

The conductivity apparatus used was the same as in the previous work but the conductivity vessel was graduated so that the volume of chlorine used in each experiment could be read. Four or five ccs. of chlorine were introduced into the cell, the volume read, and the weight calculated from the value for the density. A weighed amount of solute was added from a pycnometer. HCl gas was then slowly passed in from a small gas burette with levelling tube containing mercury, which was protected from the action of the HCl by a layer of concentrated sulphuric acid. The gas was introduced through a capillary tube leading to the bottom of the cell, and after each addition of gas the Dewar flask containing the cell was lowered sufficiently to remove the capillary tube from the liquid while measurements were being made. Readings of conductivity were taken at regular intervals until the value became constant. It was found that after each addition of HCl it took some time for a constant value to be reached. This time was as much as one or two hours for the first few additions of gas, after which it gradually decreased to ten or fifteen minutes. The change with time was invariably a steady increase except in the case of the toluol solution described later and for a small part of the alcohol curve.

Ether—Chlorine—HCl

Chlorine, 7.70 grams; ether, 1.163

The ether used was some which had been kept for several months over sodium. The values obtained are shown in Curve I. It was observed that if only a small quantity of ether (1-2 per cent.) was dissolved in the chlorine no appreciable conductivity was obtained even on the addition of four or five times the molecular equivalent of HCl. The conduction of the solution increased with each addition of acid. This was also noticed by Maass and McIntosh for the system Ether-Acid, where the maximum conducting power was found at about 8 molecules of acid to one of ether.



Ethyl Acetate—Chlorine—Acid

Chlorine, 8.21 grams; ethyl acetate, 1.065 grams

The ethyl acetate used was shaken with water to remove the alcohol, dried over calcium chloride and redistilled. The values obtained are shown in Curve II. As with ether, a fairly large proportion of ethyl acetate seemed necessary to give a conducting solution. A solution containing about 6 per cent. ethyl acetate was only beginning to show an increase in conductivity when about one molecular equivalent of acid had been added.

Acetone—Chlorine—Acid

Chlorine, 6.26 grams; acetone, 0.451 grams

The acetone used was Merck's and was redistilled. The values obtained are shown in Curve III, which is quite similar to that obtained with ether. It was noticed, on removing the conductivity cell at the conclusion of the experiment, that the liquid had separated into two distinct layers. These differed only very slightly in colour but when mixed by shaking separated again in a few moments. The constitution of these layers is a question for further investigation.

Acetone—Toluene—HCl

Acetone, 0.577 grams; toluene, 4.05 grams

The question suggested itself, does the chlorine actually play an active part in the ionization of these solutions, or is the observed conductivity due to the ether and HCl alone, the chlorine serving only to dilute the solution? To throw some light on this problem a series of measurements was made using toluene in place of chlorine. Toluene was selected as a solvent unlikely to enter into combination or exercise any ionizing effect. The toluol used was freed from water, etc., by cooling it in the ether-carbon dioxide bath and filtering several times through asbestos, until it no longer appeared turbid at that temperature. Acetone was used as the solute, approximately the same quantities being used as in the case of the acetone-chlorine measurements. The results are shown in Curve IV.

It may be seen from the graphs that there is a decided similarity between the behaviour of the chlorine and the toluene solutions, although the values for the conductivity are much smaller in the latter case. However, instead of a gradual increase in conductivity with time, after each addition of HCl, there was an immediate increase, followed by a gradual and slight decrease to a steady value.

These facts seem to indicate that the chlorine takes no part in the ionization of the solution. Apparently the chlorine oxonium compound must be largely decomposed by hydrochloric acid before a conducting solution is formed.

Summary

1. The properties of liquid chlorine as an ionizing solvent have been examined and the observations of Johnson and McIntosh confirmed. No inorganic substance was found which is ionized in this solvent and none of the ordinary organic compounds. Ether, alcohol,

acetone and ethyl acetate were found to form conducting solutions when hydrochloric acid was added to the solution.

2. The change in conductivity with increase in acid concentration, of the last-named solutions, has been measured. A gradual increase of conductivity was observed as far as the measurements were carried. Alcohol, a poor conductor, proved to be an exceptional case. A rapid increase followed by a sudden drop and then a gradual increase was observed. As the conducting substance is probably polymerized in solution, this variation in the conductivity may be attributed to a variation with concentration of the hydrochloric acid, of the relative rates of association and dissociation. It is concluded from our measurements that the conduction is due to the ionization of an oxonium acid compound by the acid and that the chlorine merely increases the resistance. Since a measurable interval of time is probably necessary to bring about equilibrium between the undissociated chlorine compound and the acid the increase in conduction is to be expected.

3. The conductivity of a solution of acetone with toluene substituted for the chlorine was measured under similar conditions. The conductivity was very much less than in the case of the corresponding chlorine solution, but the general shape of the curve is the same, and indicates similar functions in the two cases.

4. We have failed in our attempts to isolate compounds of the general type, oxygen compound-halogen-halogen acid. Some well crystallized bodies on careful examination proved to be mixtures of previously investigated oxonium halogen and oxonium acid compounds.

NOTE.—This investigation was carried out in 1919-20 by Mr. Mennie, then a bursar of the Honorary Advisory Council.

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Solubility of Cyclohexane in Liquid Sulphur Dioxide

By W. F. SEYER, PH.D., and V. DUNBAR

Presented by E. H. ARCHIBALD, F.R.S.C.

(Read May Meeting, 1922)

In 1918, in the Metallurgical and Chemical Engineering Journal, th ere appeared an article by G. J. Moore, J. Morrell and Gustave Egloff on the solubility of paraffins, aromatics, naphthenes and olefins in liquid SO_2. They claimed, in the course of this investigation, to have obtained evidence pointing to compound formation between cyclohexane and liquid SO_2. These evidences, however, seemed to be of a questionable nature, in as much as statements such as these occur in the article. "The present work, however, indicates that naphthenes vary in solubility from 0 to 100 per cent. depending upon the temperature and *concentration of* the liquid SO_2." . . . "Below 49 per cent. SO_2, that is, nearly an equal volume, there is no solubility at 18°C., and only 3 per cent at 4.5°. With *about 70 per cent SO_2, however, the solubility shows a marked increase.* One marked peculiarity of the naphthene action with SO_2 is that as the concentration of the SO_2 reached a point between 83 and 87 per cent, white crystals appeared in the oils, remaining upon the addition of more SO_2."

"This peculiarity of behaviour, together with the marked increase in solubility at about 70 per cent., seems to point to some compound between the SO_2 and the naphthenes."

In carrying out their solubility measurements the above mentioned investigators used a graduated burette stoppered at both ends. A certain amount of cyclohexane was run in and then the liquid SO_2. In this article they appear to confuse concentration of the SO_2 with the amount present in the burette, which are two very different things as the two liquids are only slightly soluble in each other over the range of temperature that they worked. In view of the above statements and the fact that Messrs. Moore, Morrell and Egloff based a method of separation of paraffins and naphthenes on these discoveries, it was thought worth while to re-determine the solubility of cyclohexane in liquid SO_2.

The cyclohexane used was obtained from the Eastman Kodak Co. It had a boiling point of 79°, freezing point of 6.4°, and showed no signs of unsaturation. It was dried by refluxing over sodium.

The sulphur dioxide used was the ordinary commercial product sold in small tanks. Special precautions were taken to purify it from all traces of water and SO_3. This was done by first bubbling the gas through water and sulphuric acid and then storing it in large bottles over concentrated sulphuric acid. After standing thus for a week, it was drawn off through a phosphorus pentoxide tube and condensed by means of a carbon dioxide ether bath.

A number of attempts were made to determine the solubility in a way similar to that used by the above mentioned workers, but no concordant results could be obtained. The great difference in the boiling point of the two substances excluded the possibility of determining the freezing points by a Beckman apparatus. Resource was, therefore, had to the bulb method.

Bulbs with a volume of about 15 c.c. were blown on the ends of tubes 10 c.m. in length. Definite weights of cyclohexane were run into the different bulbs and the dried SO_2 condensed in them, and while the temperature of the bulbs was still low, the tops of the bulbs were sealed off. They were then weighed.

At room temperatures the two liquids were miscible at all concentrations, but on cooling two layers formed. The temperature at which these two distinct layers just disappeared was recorded and is given in Table 1.

TABLE I

Solubility of the Two Liquids

Per cent. SO_2	Temp.			Per cent SO_2	Temp.		
	I	II	III		I	II	III
18	−1°.0	−1°.0	−1°.0	65.4	13.3°	13.5°	13.0
22	2°.0	1.5°	1.5	83.2	9.0	8.6	....
35.1	11°.0	11.5°	11.	87.9	4.2	4.0	4.0
40.9	11.3°	11.3°	11.3	92.2	−6.0	−6.0	−6.0
59.2	13.5°	13.6°	13.4	94	−8.0	−8.5	−8.5

If the temperature be lowered still more the cyclohexane begins to separate out in the form of colourless crystals. The super-cooling is always considerable, being in some cases as much as 15°, and in all cases as much as 10°. After a considerable amount of solid had formed the temperature was allowed to rise until a point was reached where the amount of solid phase neither increased nor decreased. The temperature was then slowly raised and the point at which the crystals disappeared was taken as the freezing point. A standardized pentane thermometer was used throughout the lower temperatures but owing to the difficulty of noting just when the crystals disappeared the freezing points cannot be taken as being correct to more than one degree.

TABLE II

TEMPERATURE AT WHICH CYCLOPHEXANE CRYSTALS APPEAR

Per cent. SO_2	Temp. at which crystals disappear		Per cent. SO_2	Temp. at which crystals disappear	
	I	II		I	II
4	− 4.5°	− 4.0°	87.9	—	—
18	−17.0°	−17.0°	92.2	—	—
22	−17.0°	—	94	—	—
35	—	—	96.7	−24.5°	−24
40.9	—	—	97.5	−34.4°	−34.1
59.2	—	—	98.4		about −51.0°
65.4	—	—	99	−57.0°	−55.0°
83.2	—	—	99.2	−61.0°	−59.0°
			99.5	−65.0°	−64.0°

Diagram I shows the curve as plotted by using the figures in both Tables I and II. If to the system, cyclohexane at 6.4° liquid sulphur dioxide is added, the temperature will fall; and continued addition of the SO_2 will lead at last to the transition point B where the maximum solubility of sulphur dioxide in oil is reached, and it begins to separate out as a separate layer. As there are now four

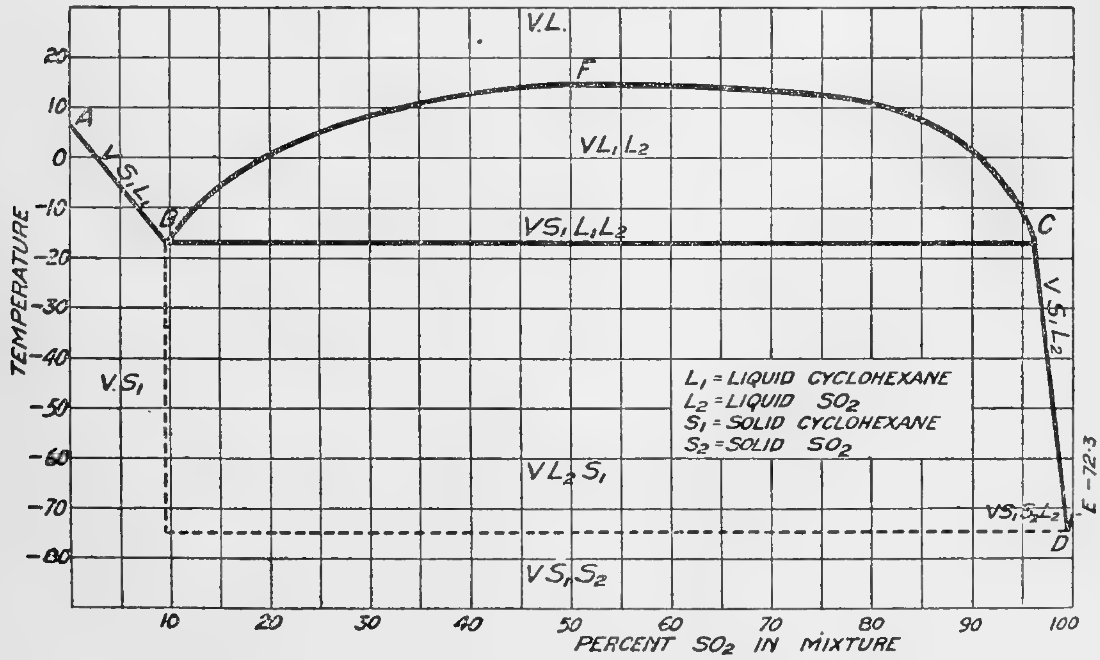

Diagram I

phases present, vapour, solid and liquid cyclohexane and liquid SO_2 the system is invariant, and a further increase in the amount of liquid sulphur dioxide can only cause a change in the relative amounts of the phases. Therefore continued addition of SO_2 will cause an increase in the amount of the liquid phase containing excess of SO_2, whereas the other liquid phase will gradually disappear. When it has completely disappeared the system will be represented by the point *C*, where there are again three phases. As the amount of solid cyclohexane is diminished the equilibrium temperature will fall until at *D* the eutetic point is reached. The temperature of the eutetic point is approximately —72.5°* but the composition of the solution was not accurately determined owing to the fact that the hexamethylene is almost completely insoluble in liquid SO_2 at these low temperatures. One part of oil showed no signs of dissolving in 200 parts of SO_2 at −72°.

If the amount of the cyclohexane is diminished still more the temperature rises until at −72.3 the freezing point of pure liquid sulphur dioxide is reached.

Along line *B C* there exist four phases, vapour, two liquids and one solid, but if heat be added the solid hexamethylene will disappear leaving a univariant system of vapour and two liquids. In general the solubility curve of two partially immiscible liquids is of a somewhat parabolic shape, and it is seen that the curve *B F C* has the general form of a parabola. Above 13.6 the critical temperature, the liquids are miscible in all proportions. This curve shows no evidence of any compound formation.

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*Obtained by extending curve *F C* to *D*.

Saha's Ionization Hypothesis

By H. H. PLASKETT

Presented by J. S. PLASKETT, F.R.S.C.

(Read May Meeting, 1922)

The work of McLennan, Franck and Hertz and others has shown that there are associated with the production of a single line spectrum, an arc spectrum, an enhanced spectrum, certain definite amounts of energy. Saha, using the Nernst Heat theorem and these known ionization potentials of various elements, has obtained a physical interpretation of stellar spectra. Inversely from the appearance of a given spectrum in a star he has been able to compute the stellar temperatures. The study of early type high temperature stars at this observatory has shown, however, that this hypothesis is open to two main criticisms.

(1) The use of the Nernst Heat theorem implies that the cause of ionization in stellar atmospheres is radiation from the photosphere (J. A. Anderson, E. A. Milne). Now some B-type stars (effective temperature 15,000°K) show the Balmer series as emission. From Bohr's theory it is possible to compute the necessary energy to enable one H atom to emit the Balmer series. From Planck's law it is likewise possible to compute the available radiation energy emitted at any wave-length per sq. cm. per sec. Carrying out the necessary computations it is found that at 15,000° K there is enough radiant energy to place 10^{20} H atoms per sq. cm. column in a disturbed condition. Of the radiation proceeding radially outward from the photosphere certain of these 10^{20} atoms will absorb at $H\gamma$ 10^6 ergs per sec. The 10^{20} atoms will emit in all directions 10^8 ergs per sec. of $H\gamma$ radiation. Of this 10^8 emitted ergs only 10^{-15} will proceed radially outward on a star the size of the sun. The net result is that if radiation is the only factor at work, at $H\gamma$ 10^6 ergs will be absorbed radially and only 10^{-15} re-emitted radially. In other words, we should only obtain an absorption spectrum. The fact that an emission spectrum is obtained shows that there must be at work a far more powerful source of ionization than radiant energy. The fact that at 15,000°K there are probably some 10^{14} free electrons per cu. cm. with velocities of thermal agitation sufficient to ionize H atoms shows that electron collisions, not absorption of radiation, is the probable cause of ionization.

(2) Saha in his theory takes no account of the relative abundance of different elements. For a spectrum to show, a certain number of atoms must be in a disturbed condition. Now, since at a given temperature and a given ionization potential a certain fraction of the atoms of an element are ionized, it is evident that of two elements of like ionization potential the more abundant will be the first to appear and the last to disappear. The neglect of this factor of relative abundance of elements accounts for Saha's prediction that the Balmer series should disappear in O-type stars (effective temperature 22,000°K) just slightly before Mg_+4481. The fact observed here that the Balmer series persists long after this stage is doubtless due to the fact that there are more H atoms than Mg in the stellar atmosphere. The analyses of Clark show that in the first 10 miles of the earth's crust there are about 12 times as many H as Mg atoms. Not only, however, must the relative abundance of elements be considered but also the possibility that the relative amounts are subject to change in the course of stellar history. We would naturally anticipate as the star grew hotter that certain of the more complex atomic nuclei would become unstable and break down into H and He nuclei. The fact that in an O-type star at 25,000°K 4686 is a broad (10 A.U.) emission line shows from Merton's experiments that He is probably much more abundant relatively than on the earth. The absence of unknown lines in such stars, whereas we would have anticipated many 9 N lines of different elements, also points to a possible change in relative abundance. It also seems probable that it is this gradual change in the relative abundance of elements that accounts for the spectral changes in giant and dwarf stars of the same temperature which have led to the determination of spectroscopic parallaxes.

In conclusion it is evident that if Saha's hypothesis is to be used to determine stellar temperatures, it will have to be modified to meet such criticisms as these.

A Note on Missing Spectra

By A. S. EVE, F.R.S.

(Read May Meeting, 1922)

Mining engineers use well-constructed sieves made of phosphor bronze wire with various sizes of mesh, ranging up to three hundred wires to the inch.

When a narrow beam of parallel light falls on the sieve diffraction bands and patterns are produced which may be observed directly, or after projection.

By a calculation involving simple proportion only the wave-length of any light can be determined.

A sieve with 300 wires to the inch was found to have the intervals between the wires precisely equal to their diameters. It necessarily follows that the even order spectra are entirely absent, while the odd order spectra are enhanced in brilliancy.

On inclining the sieve to the ray the gaps are effectively narrower while the circular wires are not, hence at about 30° the missing spectra suddenly appear.

A photograph of the 300 sieve was taken with a white screen behind it. This photograph was used as a grating and all the spectra were found present. Possibly the light flooded the plate when the photograph was taken, so that the gaps were enlarged relatively to the image of the wires. There is no new principle involved in the above, but the method is a valuable and effective method of demonstrating missing spectra.

The Spreading of Mineral Oils on Water

By R. S. JANE, B.Sc.

Presented by E. H. ARCHIBALD, F.R.S.C.

(Read May Meeting, 1922)

In view of the fact that pure saturated hydrocarbon oils do not spread on a clean surface of water, as shown by W. B. Hardy,[1] and that the spreading of some oils, as shown by Langmuir,[2] is due to the presence of an active group in the molecule, such as the double bond, it was thought that some relation might exist between the rate of spreading and the degree of unsaturation. However, the table given on the next page shows that, at least in a number of cases, the presence of the active group does not cause the oil to form a film on the surface of the water, but that it acts as one would expect a pure saturated hydrocarbon to act.

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[1]Proc. Roy. Soc. A, Vol. 86, 1912, p. 610.
[2]J. of Am. Chem. Soc., Vol. 39, 1917, p. 1881.

SPREADING OF OILS ON WATER

Oil	Iodine number	Obs. Viscosity	Density	Spreading	Analysis of a few of the oils
Vacuum, 73	37.9	.1705	.8563	Fast—but not extensively	C=86.664% H=13.271% S= 0.000%
" 431	43.2	.5310	.8975	no spreading	
" 448	31.7	.2910	.8683	" "	C=86.85% H=13.24% S= 0.0
" 92	35.2	.3590	.8925	" "	
Polarine, 1	30.0	.3480	.8925	Very fast—and extensively	
" 2	23.1	.4625	.9031	" " " "	H=13.21% C=86.77% S= 0.00
" 3	29.9	.9260	.9120	Rather slowly—not extensively	
" 4	39.2	.8550	.9044	No spreading	
Monogram	29.4	.3910	.8766	Very fast—and very extensively	
Veedol	38.0	.7660	.8953	Not so fast that progress of film can not be seen	
Petrolatum	00.0	.3510	.86227	No spreading (as would be expected)	H=14.20% C=85.77% S=0.00
$\frac{N}{20}$ Stearic Acid Solution in Petrolatum	....	.....	.....	Very fast and extensively	
$\frac{N}{20}$ Oleic Acid Solution in Petrolatum	....	.....	.....	" " " "	
*Vacuum oil treated with Liquid SO_2 73	18.4	.....	.....	No spreading	H=14.10% C=85.95%
* " " " " " " 431	15.4	.....	.....	" "	
* " " " " " " 448	14.5	.....	.....	" "	
*No. 2 Polarine treated with Liquid SO_2	5.8	.....	.....	" "	H 13.33 C=86.66 S=00.0

*These oils were treated with Liquid Sulphur dioxide until no more unsaturated compounds would dissolve out.

On the Excitation of Characteristic X-rays from Light Elements

By PROFESSOR J. C. MCLENNAN, F.R.S., and
MISS M. L. CLARK, B.A.,
of the University of Toronto

(Read at May Meeting, 1922)

Abstract

I. INTRODUCTION

In an attempt to fill up the gap between the shortest ultra-violet light waves hitherto produced and the longest X-ray waves known, Hughes[1] recently made a study of the characteristic X-rays emitted by carbon and by boron when bombarded by electrons. In this investigation the energy of the bombarding electrons was increased by steps, and the critical values were determined that were necessary and just sufficient to cause the bombarded element to emit its characteristic radiations with measurable intensities. These characteristic radiations were detected and their intensities measured by their photoelectric action on an insulated electrode of nickel or of silver.

The method followed by Hughes in recording his results was to plot curves with the values of the accelerating potentials of the electrons as abscissae and the measures of the photoelectric effect divided by the corresponding electronic currents as ordinates. At certain critical accelerating voltages it was found that these curves showed marked and abrupt kinks or changes of curvature and these changes were taken to connote the beginning of the emission by the bombarded element of its characteristic radiations.

By following this method he found two definite breaks in his curves for both carbon and boron, and these were taken by him to correspond to the critical K and L absorption wave-lengths for the two elements. For carbon the breaks occurred at 215 volts and 34.5 volts and for boron at 148 volts and 24.5 volts.

This would mean that the critical absorption wave-lengths of the K and L X-ray series for carbon were about λ 57.5A and λ 358A respectively, and for boron about λ 83.5A and λ 505A respectively.

Hughes' results appear to be the only ones as yet obtained with the element boron, but with carbon other researches have been

[1]Hughes, Phil. Mag., Jan., 1922, p. 145.

carried out and differing values have been found for the critical absorption wave-lengths of the K and L series for this element. Kurth's[1] values are λ 42.6A (Acc. Pot. = 283 volts) and λ 375A (Acc. Pot. = 32.9 volts) respectively. Richardson and Bazzoni's[2] value for the K series is λ 43.4 A (Acc. Pot. = 286 volts) while Mohler and Foote's[3] results for the K series give λ 45.4 A (Acc. Pot. = 272 volts).

Hughes' value for the critical absorption wave-length of the K series of carbon, it will be seen, is considerably higher than any of the values found by the other investigators.

In an investigation recently carried out by the authors in which the method followed was that adopted by Hughes, the critical absorption wave-lengths of the K and L series were determined for the elements boron, beryllium, and lithium and the critical absorption wave-length of the L series for carbon. The apparatus used was made of pyrex glass and is shown in Fig. 1.

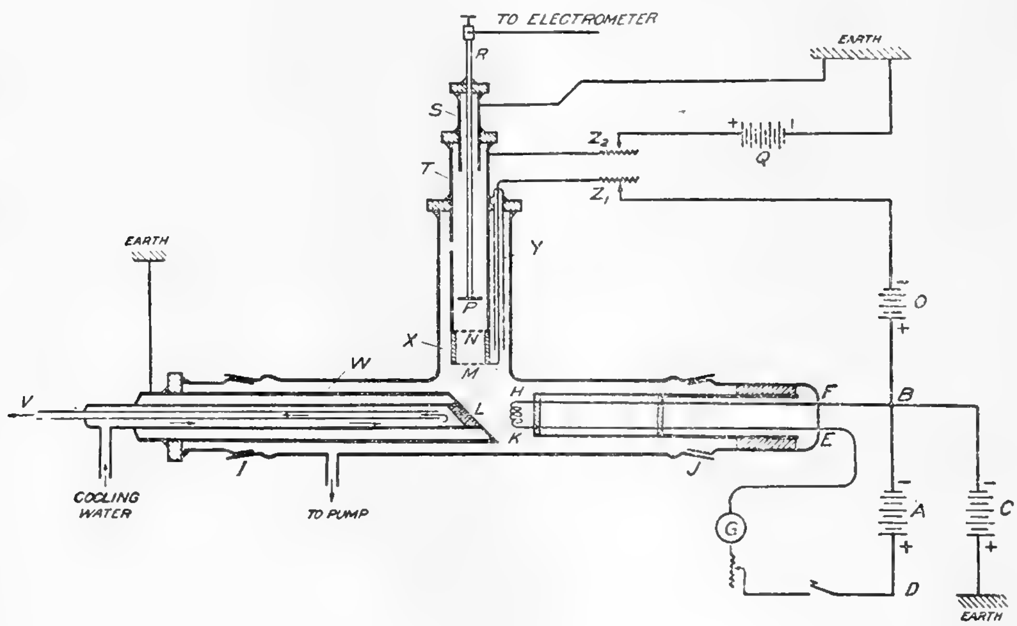

FIG. 1

II. Results

The critical potentials found in the investigation for the elements lithium, beryllium, boron, and carbon are classified by the authors either as high or low range critical voltages.

[1]Kurth, Phys. Rev., Dec., 1921, p. 461.
[2]Richardson and Bazzoni, Phil. Mag., Dec., 1921, p. 1015.
[3]Mohler and Foote, Scien. Papers, Bur. of Standards, No. 425, 1922.

A. *High Range Critical Voltages, and K Series Spectra*

Lithium

For lithium high range critical potentials were found at 31.8 and 37 volts. As these values are approximately in the ratio 27 to 32, it was concluded that they represented the first two members of a series with a frequency formula $\gamma = A\left(1-\frac{1}{m^2}\right)$. Such a series would have 42.4 volts for the quantum potential of its shortest member. This voltage was taken to represent the critical absorption wave-length of the K X-ray series of lithium.

Beryllium

For beryllium critical potentials were found at 78.2 and 93.0 volts. From them the authors deduced 104.3 volts as the potential corresponding to the critical absorption wave-length of the K series of this element.

Boron

For this element only one critical potential was found, viz., 147 volts, and this has been taken to be the quantum equivalent of the shortest member of the K series for boron.

Table I contains the critical potentials found for lithium, beryllium, and boron. It also contains values found with the photoelectric method by Richardson and Bazzoni, Kurth, Hughes, or Mohler and Foote, for carbon, nitrogen and oxygen. For the elements heavier than oxygen, the values tabulated were taken from "Data relating to X-ray Spectra" (Bulletin of the National Research Council, No. 6, Nov., 1920). The ionisation potentials for helium and hydrogen are also given in the Table.

TABLE I

CRITICAL K SERIES ABSORPTION WAVE-LENGTHS

Element	At. No.	Critical Potential V (Volts)	$\sqrt{V}$	Critical absorption wave-length $\times 10^8$
Potassium	19	3590.3	59.9	3.44 cm.
Argon	18	3189.8	56.5	3.86
Chlorine	17	2812.5	53.0	4.38
Sulphur	16	2460.1	49.6	5.01
Phosphorus	15	2141.5	46.3	5.76
Aluminium	13	1552.0	39.4	7.95
Magnesium	12	1296.0	36.0	9.51
Oxygen	8	498.0	22.3	24.76
Nitrogen	7	374.0	19.34	33.0
Carbon	6	259.3	16.1	47.6
Boron	5	147.5	12.15	83.6
Beryllium	4	104.3	10.2	118.2
Lithium	3	42.4	6.5	290.8
Helium	2	25.4	5.05	485.5
Hydrogen	1	13.5	3.67	913.4

The curve No. 1 corresponding to the numbers in Table I is shown in Fig. 2.

From the form of the curve (1) it is evident that for the elements cited from potassium to lithium, the square roots of the critical potentials are very closely proportional to the respective atomic numbers, that is, the Moseley law applies. For helium and hydrogen the square roots show only a slight departure from the linear relation which goes to confirm the view that it is now customary to take regarding the spectrum of hydrogen, namely, that the Lyman series is the K series for this element. From the curve and the values given in Table I, it would appear that the critical absorption wave-lengths of the K X-ray series for silicon, sodium, neon, and fluorine, which have not as yet been found experimentally, should be 6.73×10^{-8} cm, 11.46×10^{-8} cm, 14.46×10^{-8} cm and 18.4×10^{-8} cm respectively.

B. *Low Range Critical Potentials and L Series Spectra*

Lithium

With lithium a well marked critical potential was found at 12 volts, which, in the light of Bohr's discussion of the structure of the atom of lithium, was taken to be the quantum equivalent of the

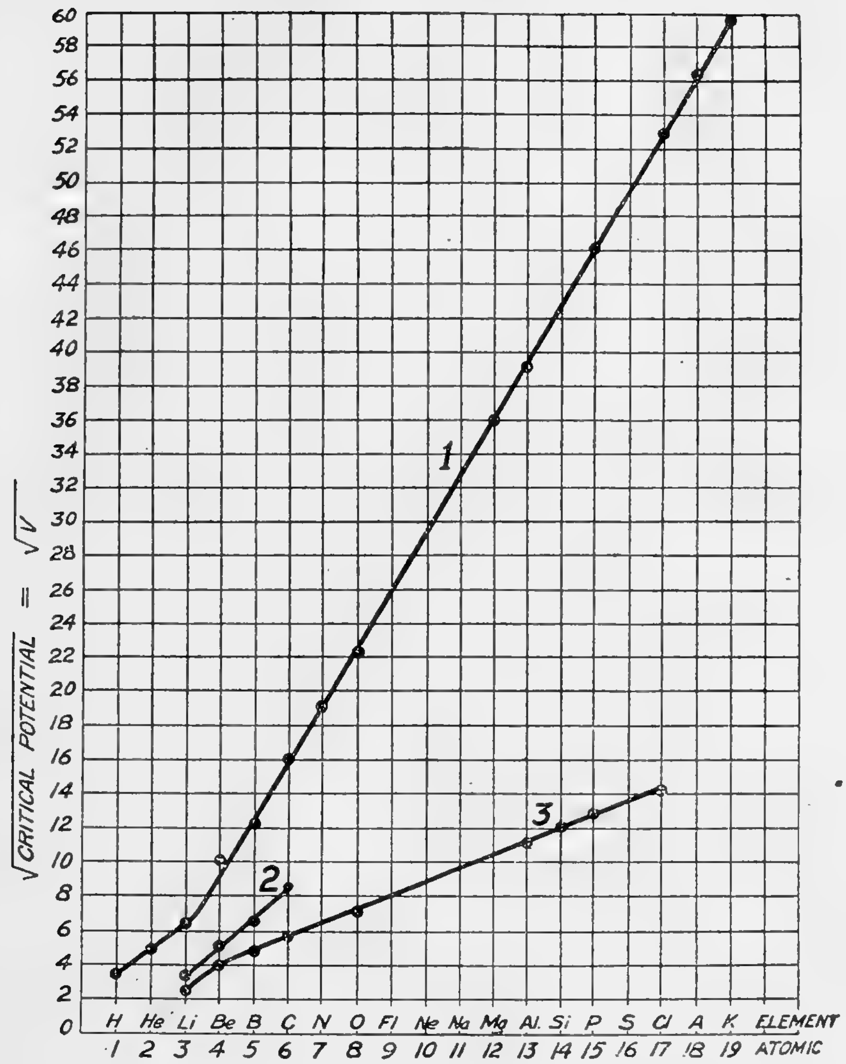

Fig. 2

shortest wave-length of the L X-ray series of this element. A value of 6.7 volts was deduced as the quantum equivalent of $L\alpha$ for lithium. The apparatus used was probably not sufficiently sensitive to bring out this critical potential.

Beryllium

With beryllium critical potentials were obtained at 16 and 20.3 volts. As these values are approximately in the ratio 20 : 27 they were interpreted as representing the first two members of the L series for beryllium. On this interpretation the quantum equivalent of the shortest member of the L X-ray series of beryllium would be about 28.8 volts.

Boron

For boron critical potentials were observed at 23.45 and 27.92 volts and these were taken to represent the first two members of the *L* series for this element. A value of 42.2 volts was deduced for the quantum equivalent of the shortest member of the *L* series for boron.

Carbon

With carbon critical potentials were observed at 33 volts and 72 volts. Some difficulty was experienced in interpreting these results. Millikan[1] in photographing the extreme ultra-violet spectrum of carbon found that it terminated at λ 360.5 *A*. This, he concluded, was the shortest member of the *L* series of the element. As the quantum equivalent of λ 360.5 *A* is 34.2 volts, it would seem natural to interpret the potential of 33 volts as corresponding to the limiting frequency of the *L* series. This interpretation would, however, leave the critical potential of 72 volts unexplained. The potentials 33 volts and 72 volts were therefore tentatively assumed to represent the first and last members of the *L* series for carbon, an assumption which fitted in with the interpretation given above for the critical potentials found for lithium, beryllium and boron.

Table II contains the values of the critical potentials found in this part of the investigation together with values found with the ionisation method for other elements by either Kurth or Mohler and Foote. The Table also contains the atomic numbers of the elements, the square roots of the critical potentials and the quantum equivalent wave-lengths of these potentials.

TABLE II

CRITICAL VOLTAGES AND *L* SERIES WAVE-LENGTHS

Element	At. No.	Critical potential V	$\sqrt{V}$	Wave length $\times 10^8$	Critical potential V	$\sqrt{V}$	Wave-length $\times 10^8$
		volts			volts		
Lithium.....	3	6.7	2.6	1840.0 cm.	12.0	3.47	1019.0 cm.
Beryllium...	4	16.0	4.0	770.7	28.8	5.36	428.1 "
Boron.......	5	23.45	4.84	525.8	42.2	6.5	292.2 "
Carbon	6	33.00	5.74	373.7	72.0	8.5	171.1 "
Oxygen......	8	49.72	7.1	248.0			
Aluminium..	13	123.3	11.1	100.0			
Silicon......	14	149.5	12.23	82.5			
Phosphorus..	15	163.0	12.8	75.6			
Chlorine.....	17	198.0	14.07	62.3			

[1]Millikan, Ast. Phys. Jl., Vol. LII, No. 1, p. 61, July, 1920.

The results are plotted in Fig. 2, where it will be seen they fall into two sets, the one represented by Curve No. 2 and the other by Curve No. 3.

On the basis of the interpretation given above, Curve No. 2 would correspond to the convergence frequencies of the L series of the elements named and Curve No. 3 to the frequencies of the first members of these series.

With the object of showing how this interpretation of the observed critical potentials fitted in with the known values of the emission L series wave-lengths of the heavier elements, a limited number of these were selected and are given in Table III. The values given are those of the longest and of the shortest known L waves of the elements selected, and have been taken from Duane's Tables. The square roots of the quantum voltages of these wave-lengths are plotted against atomic numbers in Fig. 3, the values given in Table II are also plotted in the same figure, and in order to make the record as complete as possible, the square roots of additional critical voltages observed by Mohler and Foote for chlorine, sulphur, phosphorus, magnesium, sodium, and potassium, and by Richardson and Bazzoni for molybdenum are marked on the diagram. These additional critical voltages are given in Table IV.

TABLE III

L Series Wave-lengths

Element	At. No.	Longest observed wave-length			Shortest observed wave-length		
		$\lambda\times10^8$	V (volts)	$\sqrt{V}$	$\lambda\times10^8$	V (volts)	$\sqrt{V}$
Zinc	30	12.346 cm α_1	1000.0	31.6	[illegible]		
Bromine	35	8.391 " α_1	1469.5	38.2	8.141 cm β_1	1514.6	38.9
Rubidium	37	7.335 " α_1	1681.1	41.0	7.091 " β_1	1739.2	41.7
Strontium	38	6.879 " α_1	1792.6	42.3	6.639 " β_1	1857.4	43.1
Zirconium	40	6.083 " α_1	2027.1	45.0	5.386 " γ_1	2289.4	47.9
Molybdenum	42	5.410 " α_2	2279.3	47.7	5.175 " β_1	2382.8	48.8
Palladium	46	4.374 " α_2	2819.1	53.1	3.597 " $\gamma_2-\gamma_3$	3150.1	56.1
Cadmium	48	3.959 " α_2	3114.7	55.8	3.328 " γ_1	3705.2	60.9
Tin	50	3.604 " α_2	3421.5	58.5	2.831 " γ_4	4355.7	66.0
Antimony	51	3.443 " α_2	3521.5	59.8	2.782 " $\gamma_2-\gamma_3$	4432.4	66.6
Caesium	55	2.899 " α_2	4253.5	65.2	2.234 " $\gamma_2-\gamma_3$	5519.7	74.3
Cerium	58	2.573 " α_2	4788.6	69.2	2.003 " $\gamma_2-\gamma_3$	6156.25	78.5
Neodymium	60	2.379 " α_2	5183.3	72.0	1.775 " γ_3	6947.04	83.4
Europium	63	2.131 " α_2	5786.5	76.1	1.510 " γ_3	7755.3	88.6
Erbium	68	1.794 " α_2	6873.5	82.9	1.316 " γ_3	9370.0	96.8
Tungsten	74	1.675 " ϵ	7361.8	85.8	1.026 " γ_4	12018.5	109.6

TABLE IV

MISCELLANEOUS CRITICAL POTENTIALS

Element	At. No.	V (volts)	$\sqrt{V}$	$\lambda \times 10^8$	Investigator
Sodium........	11	35	5.91	353	Mohler and Foote
		17	4.12	725	
		5.11	2.26	2412.63	Limit of doublet series (M)
Magnesium....	12	46	6.78	268	Mohler and Foote
		33	5.74	374	
Phosphorus....	15	126	11.22	98	" " "
		110	10.49	112	
		95	9.8	130	
Sulphur.......	16	152	12.33	81.2	" " "
		122	11.05	101.0	
Chlorine.......	17	157	12.53	78.6	" " "
Potassium.....	19	23	4.8	537	" " "
		19	4.36	650	
Molybdenum...	42	356	18.9	34.8	Richardson and Bazzoni

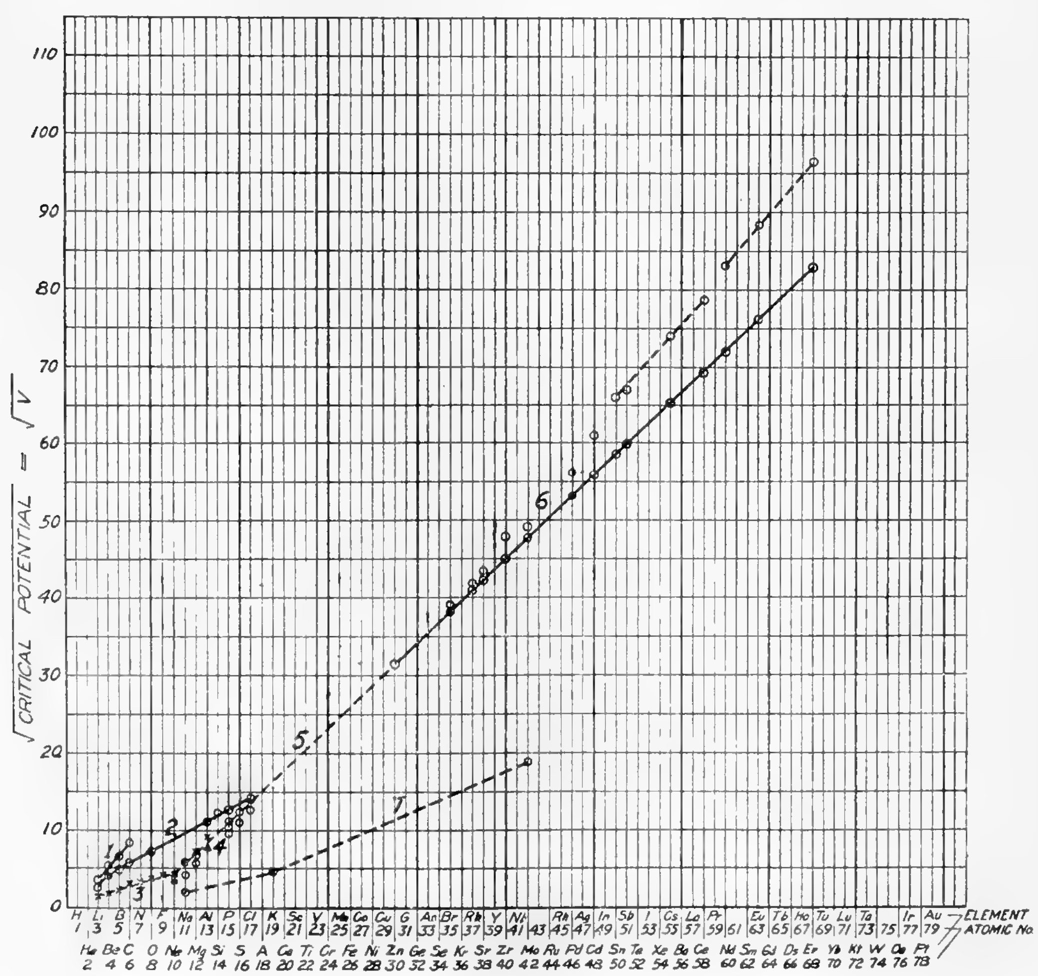

Fig. 3

The diagram in Fig. 3 brings out the well-known fact that for the heavier elements both the longest L waves and the shortest ones as well follow closely the Moseley Law, *i.e.*, that $\sqrt{V}$ is proportional to At. No. The diagram also shows that for the lighter elements from lithium to chlorine the square roots of the critical voltages cited follow a similar law, but the proportionality factor between $\sqrt{V}$ and At. No., however, is not the same for the lighter elements as for the heavier ones. It is evident that according to the representation a break occurs at or near chlorine or argon.

The paper also points out that in a series of brilliant experiments Millikan[1] and his associates recently succeeded in photographing extreme ultra-violet spectra of light elements as far down as λ 136.6 A and that from the results determinations were made by him of the quantum voltages of the limiting frequencies of the L series of the elements from Lithium to Magnesium. The photographic results also enabled him to estimate quantum voltages corresponding to the first members of the L series for these elements. These are given in Table V and along with them are given critical voltages found by Horton and Davies for Neon and a critical voltage found directly by Holweck for Aluminium.

TABLE V

Column I Element	Column II Wave-length of $L\alpha$	Column III V=Quantum equivalent Potential (Volts)	Column IV $\sqrt{V}$
Lithium	6708 A	1.84	1.36
Beryllium	3131 A	3.94	1.98
Boron	2497 A	4.94	2.22
Carbon	1335 A	9.24	3.04
Nitrogen	1085.3 A	11.36	3.36
Oxygen	840.0 A	14.7	3.83
Fluorine	657.2 A	18.76	4.3
Neon	1045 A	11.8[2]	3.43
	693 A	17.8	4.22
Sodium	376.5 A	32.75	5.72
Magnesium	232.2 A	53.11	7.25
Aluminium	144.3 A	85.6	9.26
	193.0 A	63.9[3]	7.99

[1]Millikan. Proc. Nat. Acad. Sci. 7, p. 289, 1921.

[2]From direct determinations. Horton and Davies. Proc. Roy. Soc., No. 98, p. 121, 1920.

[3]From direct determinations. Holweck. Ann. de Physique, Jan., Feb., 1922.

The values given in Column IV, Table V, are recorded in Fig. 3, those obtained from Millikan's work being indicated by crosses, those by Horton and Davies by squares and that found by Holweck by a triangle. The values given in Table IV are indicated by circles. The graph denoted by No. 7 is taken to correspond to M X-ray series of the elements tabulated.

Curves Nos. 4 and 5, extensions of the line No. 6, it will be seen pass through and fit in fairly well with values of $\sqrt{V}$ given in Tables IV and V for the elements from Chlorine to Neon. From Neon to Lithium the values of $\sqrt{V}$ lie approximately on a line designated in the diagram as Curve No. 3.

If we accept the values of the critical voltages given in Tables IV and V, as the correct ones for the quantum equivalents of the first numbers of the L series for the corresponding elements, the graphs shown in Fig. 3 would indicate that the Moseley L series Law applies very closely for all elements from Uranium to Neon. For the elements lighter than Neon the square roots of the critical voltages lie on a line, which is slightly concave, towards the atomic number axis but which meets the line representing Moseley's Law at the element Neon.

If we conclude that the graph Nos. 3, 4, 5, and 6 correctly represents the square roots of the quantum voltages for the $L\alpha$ wave-lengths of the elements cited, strong support is given to the view that in all atoms heavier than Fluorine, the second shell or ring consists of eight electrons and that the L series wave-lengths for all elements including the lighter ones, originate in disturbances given to the electrons in the group comprising the second ring or shell.

In the endeavour to interpret the numerous and varied critical potentials that have been found experimentally by a number of investigators, including the authors, two views have been presented. According to one, the Moseley L series law is applicable for all elements from Uranium to Argon. According to the other, the Moseley law is applicable for all elements from Uranium to Neon. If we accept the second view the critical potentials found by the writers and by Richardson and Bazzoni, Hughes, Kurth, and Mohler and Foote are left unexplained. On the other hand, if we accept the first view, the correctness of Millikan's interpretation of his photographically recorded spectra of the light elements is called in question. It is clear that while very distinct and interesting advances have been made in this field of research, further work will have to be done in order to remove a few anomalies that still exist in connection with determinations of the L series wave-lengths of the light elements.

On the Structure of the Wave-length $\lambda = 6708$ Å.U. of the Isotopes of Lithium

By Professor J. C. McLennan, F.R.S., and Mr. D. S. Ainslie, M.A.

(Read May Meeting, 1922)

Abstract

In this investigation a study has been made of the structure of the lithium red line $\lambda = 6708$ Å.U. by using a vacuum arc in the vapour of the metal and by using both Lummer plates and a 30 plate Echelon grating crossed with a Lummer plate to effect the resolution.

It has been shown that with strong arcs the wave-length $\lambda = 6708$ Å.U. consists of two doublets, with a separation of the doublet components of 0.128 Å.U. and 0.165 Å.U. respectively. The mean displacement of the two doublets was found to be 0.32 Å.U., which is between 3 and 4 times the displacement demanded on Bohr's theory for isotopes of lithium having atomic weights six and seven.

Attention is drawn in the paper to the results obtained by Merton and by Aronberg in studying the wave-length $\lambda = 4058$ Å.U. in the spectrum of ordinary lead and in that of lead having a radioactive origin. In these experiments it was found that the observed difference in wave-length was between 80 and 90 times as great as the difference to be expected on Bohr's theory.

With both lead and lithium it seems that in what would appear to be isotopic spectral displacements the value found by observation is about the atomic number times the value obtained by calculation on the basis of Bohr's theory.

The Absorption of λ 5460.97 A by Luminous Mercury Vapour

By Professor J. C. McLennan, Mr. D. S. Ainslie, M.A., and Miss F. M. Cale, B.A.[1]

(Read May Meeting, 1922)

Abstract

In this investigation experiments were made to ascertain what component wave-lengths of those constituting the mercury green line λ 5460.97 *A* are absorbable by luminous mercury vapour. As a result of this investigation it has been shown:

(1) That when the radiation constituting the green line of mercury is passed through moderately luminous mercury vapour the main component and the components No. $(+1)\Delta\lambda = 0.0086A$ and No. $(-1)\Delta\lambda = 0.0087A$ can be strongly absorbed.

(2) That no marked absorption by luminous mercury vapour was observed in the case of the other nine components of the green line.

(3) That of the nine members constituting the magnetically resolved green line it was found that the central undisplaced member was the only one that could be markedly absorbed by luminous mercury vapour.

(4) That absorption by luminous mercury vapour of the light constituting the green line in the spectrum of mercury affords a means of clearly and easily demonstrating the existence of those components of the line with separations $\Delta\lambda = 0.0182\,A$ and $\Delta\lambda = 0.021\,A$, i.e., satellites Nos. (+2) and (−2).

(5) Some considerations have been presented in support of the view that the components of the green line of mercury for which $\Delta\lambda = +0.0182\,A$, $+0.0086\,A$, $-0.0087\,A$ and $-0.021\,A$ may originate in atoms of the element having respectively the weights 197, 198, 202 and 204.

[1]Miss F. M. Cale has been enabled to proceed with research work through the award to her of a bursary by the Honorary Advisory Council for Scientific and Industrial Research of Canada.

Asymptotic Planetoids

By PROFESSOR DANIEL BUCHANAN, M.A., Ph.D., F.R.S.C.

(Read May Meeting, 1922)

(*Abstract*)[1]

Near the two vertices of the equilateral triangles which may be described on the line joining the sun and Jupiter, as base and in the plane of Jupiter's orbit, are to be found six planetoids, four at one vertex and two at the other, These six planetoids are in the vicinity of two of the five well-known points of libration in the problem of three bodies. The other three points are collinear and lie on the line joining the sun and Jupiter. One point lies between the sun and Jupiter, another on the side of the sun remote from Jupiter, and the third on the side of Jupiter remote from the sun. In the case of the sun and the earth, one of these straight line equilibrium points, viz., the one on the side of the earth remote from the sun, has a physical significance in that it may account for the Gegenschein. The equilateral triangle points of libration were first considered by Lagrange, in his celebrated prize memoir of 1772, as "pure curiosities," but recent astronomical discovery has shown that these points likewise have some physical significance attached to them.

The problem considered in this paper is to determine orbits for the above mentioned planetoids, which will be asymptotic to the equilateral triangule points of libration, that is, orbits which will approach these points as the time approaches infinity. We have designated planetoids which move in such orbits as "Asymptotic Planetoids." The masses of these planetoids are not considered to be infinitesimal, and their perturbations upon the sun and Jupiter are determined. The orbits which have been found are of spiral type. They are two-dimensional and lie in the plane of Jupiter's orbit.

The differential equations of motion are integrated, according to the methods of Poincaré,[2] as power series in terms of the type $e^{ct}P(t)$, where c is a constant whose real part is different from zero, and $P(t)$ is a periodic function of t, or, in particular, a constant. Suppose $c=a+\sqrt{-1}\,b$. Then the orbits will approach the equilibrium points

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[1]The paper will appear in an early issue of the Transactions of the American Mathematical Society.

[2]Les Méthods Nouvelles de la Mécanique Céleste, Vol. 1.

as t approaches plus or minus infinity, according as a is negative or positive respectively. Such exponents as c are called by Poincaré the "characteristic exponents." Eight of them arise in the problem under consideration and these occur in pairs differing only in sign, this being the case, as Poincaré has shown,[3] in all problems in mechanics in which there is a conservative system. Two of the exponents are zero, two are purely imaginary, and the remaining four are complex, having their real parts different from zero. The solutions which approach the equilibrium points as t approaches plus infinity, desingated in the paper as "future orbits," are expanded as power series in $e^{c_1 t}$ and $e^{c_2 t}$ where $c_i = -|a_i| + \sqrt{-1}\, b_i$, $(i=1, 2)$, and those which approach the equilibrium points as t approaches minus infinity, designated "past orbits," are expanded as power series in $e^{-c_1 t}$ and $e^{-c_2 t}$. Now to each exponent such as c_1 or c_2 there corresponds one degree of freedom in the solutions. Hence both the "future" and "past" orbits have two degrees of freedom.

The following geometric property of the orbits has been found. Let the vertices of the equilateral triangle points be denoted by I and II. Then there are two orbits approaching each vertex, the "future" and the "past." A designation, such as "past II," means the orbit which approaches the vertex II as t approaches minus infinity, and similarly for the other orbits. Now it has been found that the orbit "past II" may be obtained from "future I" by changing the sign of t in the latter and then reflecting in the x-axis (rotating). The same relation exists between "past I" and "future II." This is a sort of converse of "history repeating itself" between the North and South.

The paper concludes with numerical examples in which particular values are assigned to the three bodies and the degrees of freedom specified to be arbitrary displacements, parallel to the x-axis, of the planetoid and Jupiter from the vertices of the triangle. The magnitudes of these displacements are restricted, however, by certain convergence conditions. The orbits which have been computed are drawn to scale.

[3]Loc. cit., Vol. 1, Chap. IV.

A Simple Method of Constructing Models for Demonstrating the Structure of Organic Crystals

By A. Norman Shaw, D.Sc.

Presented by Dr. A. S. Eve, F.R.S., F.R.S.C.

(Read May Meeting, 1922)

Abstract

A model constructed with rubber balls and needles was exhibited to the Society. It embodied the results of the important work of Sir William Bragg on the structure of naphthalene crystals,[1] showing clearly the arrangement of the atoms and the relative dimensions of the various spacings.

The value of such a model can only be indicated in part by a photograph, but it will be quite evident from the illustration that a model of this type should greatly facilitate the teaching and the full appreciation of these recent results about the structure of complex organic crystals.

The black balls represent the carbon atoms and the white balls the hydrogen. The scale of the model is such that the length of one molecule corresponds to 8.69 A.U. A single molecule (not quite on the same scale) is shown separately in the front of the photograph, and it will be seen that it can be identified at once from its similarity to the diagram for the conventional method of representing the double benzene ring with α and β hydrogen atoms attached. Ten molecules (*i.e.*, 180 balls) are required to represent the unit parallelepiped cell in this model, although obviously these are shared by neighbouring cells and there are really only two molecules per cell in any given crystal of naphthalene.

A brief review of Sir William Bragg's experimental work was given, and other models were shown to illustrate the relation between the structures of diamond and of graphite, with special reference to the identification and spacing of the carbon rings which appear in each case. The persistent appearance of these rings constituted the main clue in the deduction of a structure which was entirely compatible with the results of X-ray analyses.

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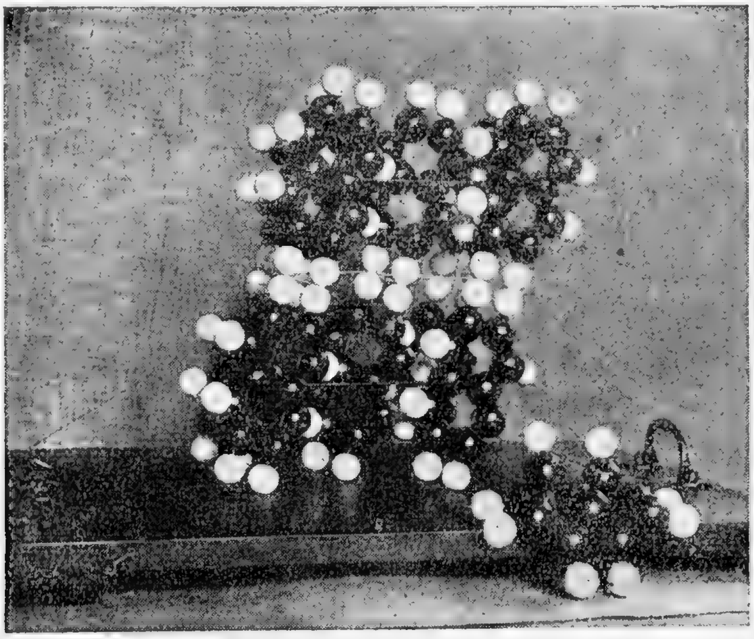
[1]Sir William Bragg, Proc. Phys. Soc. Lon., Vol. 34, p. 33 (Dec., 1921).

The object of exhibiting these models to the Royal Society was solely to inform others about what has proved to be an exceptionally good aid to lectures on this subject, in particular to classes studying molecular physics, and to students in organic chemistry becoming acquainted with this new work for the first time.

The simple method of using solid rubber balls and needles, which may be obtained cheaply and assembled readily, appears to be novel, but the writer does not in any way suggest that models of this type are new.



Model of Napthalene Crystal Cell [*Shaw*]

A Note on the Comparison of Some Formulae for the Prediction of Estuary Tides

By A. N. Shaw, D.Sc.

Presented by A. S. Eve, D.Sc., F.R.S.C.

Abstract

A brief comparison was submitted of the equations for the relationship between tides at various places on an estuary, as determined (1) on the basis of the observed "projection" relationship, (2) on the basis of some theoretical solutions.

The paper was not submitted for publication as it will be incorporated with the complete report on this work.

On an Experimental Method of Determining the Relative Effects of Radiation and Convection in Still or Moving Air on the Change in Temperature of a Body in a Given Situation.

By L. H. Nichols, B.A.

Presented by A. S. Eve, D.Sc., F.R.S.C.

(Read May Meeting, 1922)

Abstract

This method consists essentially in observing the influence of incident heat radiation and of turbulent atmospheric conditions on the rates of cooling of a pair of large alcohol thermometers (Kata Thermometers[1]) previously heated above 40°C., one of which has its bulb silvered and polished.

A preliminary calibration is made by the determination of the rates of cooling of the unsilvered thermometer in a very high vacuum and again in stagnant air when surrounded by enclosures at temperatures subsequently required.

This data, together with records of the rate of cooling of the two thermometers under the conditions to be tested, and the temperature of the air given by a screened thermometer, suffice to enable one to determine the relative influence of the main factors, *e.g.*, incident heat radiation and air currents.

The applications of this method are numerous. In particular it should be possible to allow completely for the influence of solar radiation and atmospheric turbulence upon the readings of various instruments which are at present considered unreliable under open air conditions. The comparative analysis of heating by radiation and heating by convection has important physical bearings and may be facilitated by measurements of this kind.

As further applications of the method are being developed the completed paper will not be submitted for publication until a later date.

Many thanks are due to Dr. A. N. Shaw for suggesting the problem and for valuable advice and to Mr. R. J. Clark, B.A.,for invaluable assistance in obtaining high vacua and in the making of apparatus.

[1]Hill, Griffith and Flack, "The Measurement of the Rate of Heat-loss at Body Temperatures by Convection, Radiation and Evaporation." Phil. Trans. Roy. Soc., B., Vol. 207, p. 201 (1915).

On the Theory of Dispersion and Scattering of Light in Liquids

By Louis V. King, D.Sc.,
McGill University

(Read May Meeting, 1922)

Abstract

The theory of dispersion and scattering according to the classical electron theory is revised in the light of recent views as to the lack of symmetry in the quasi-electric forces controlling vibrations in the molecule. New dispersion and scattering formulae are obtained in satisfactory agreement with recent observations.

On the Electrical and Mechanical Characteristics of a New High Frequency Vibration Galvanometer

By Louis V. King, D.Sc.,
McGill University

(Read May Meeting, 1922)

Abstract

An account of the detailed characteristics of the 1000 cycle vibration galvanometer described in a previous paper. The sensitivity, sharpness of resonance, effective resistance and reactance at various frequencies have been determined for the most recent design.

On the Numerical Computation of Elliptic Functions

By Louis V. King, D.Sc.,
McGill University

(Read May Meeting, 1922)

Abstract

Continuing previous researches on the numerical calculation of the complete elliptic integrals of the first and second kind in terms of the arithmetico-geometrical scale, new formulae have been found which make it possible to evaluate directly by means of a modern calculating machine not only the incomplete integrals of the first and second kind, but also the various cases which arise in the discussion of the incomplete third elliptic interval.

Observations on the Sterol Colour Reactions

By G. Stafford Whitby

Presented by Dr. R. F. Ruttan, F.R.S.C.

(Read May Meeting, 1922)

Abstract

Observations made with the object of elucidating the mechanism of the reactions usually used for the detection of sterols indicate that in their general character all or most of these reactions are in essence similar, their common feature being the production from the sterol, in an anhydrous medium, of a substance which couples, to give a coloured product, with another substance, derived from the sterol or from a dehydrating agent. In all the reactions some means (sulphuric acid, acetic anhydride, zinc chloride, acetyl chloride, benzoyl peroxide) of rendering the medium anhydrous is employed. The coloured product is very sensitive to traces of moisture. The actual colour obtained depends upon both the thoroughness with which the medium is dehydrated and the nature of the coupling substance. The substance produced initially from the sterol and then undergoing coupling is probably a cholesterilene or cholesteriline produced by the withdrawal of the elements of water from the sterol molecule; or, not improbably, more than one of these hydrocarbons is involved. Some of the coloured products derivable from sterols are insoluble in certain solvents (particularly carbon tetrachloride and ethyl bromide) and can be isolated by carrying out the colour reactions in such solvents.

It is found that the introduction of formaldehyde to serve as the coupling substance enables colour reactions to be obtained with quantities of sterol smaller than those with which reactions can be obtained in its absence. Two new tests, based on this observation, have been devised. One of them, which may be regarded as an elaboration of the Salkowski reaction, is considerably more sensitive and striking than the latter. The other is more sensitive than any of the reactions hitherto available for the detection of sterols. There is also described a third new reaction, the special interest of which is that it enables cholesterol to be distinguished from phytosterol. The behaviour of amyrin and abeitic acid in these tests is recorded.

Esters of Palmitic and Stearic Acids

By G. STAFFORD WHITBY and W. R. McGLAUGHLIN

Presented by DR. R. F. RUTTAN, F.R.S.C.

(Read May Meeting, 1922)

Abstract

The methyl, ethyl, propyl, *n*-butyl, *n*-amyl, octyl, and cetyl esters have been prepared by the interaction of the silver salt and the alkyl halide. In each series the melting-points do not rise continuously, but fall to a minimum in the butyl compounds; the refractive indices rise continuously. The *iso*-amyl and benzyl esters have also been prepared. Cetyl stearate has been isolated from permaceti by fractional crystallization from ether.

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PRESIDENTIAL ADDRESS

By W. A. PARKS, PH.D., F.R.S.C.

The Development of Stratigraphic Geology and Palaeontology in Canada

(Read May Meeting, 1922)

L'Abbé Jean Etienne Guettard (1715-1786) was one of the first to abandon the theories of the cosmologists, to abstain from speculation and to found geological conclusions on the secure basis of observed facts. He recognized that the strata of the earth are the documents of its history and planted the first seeds of geology as an historical science. This remarkable man was the first Canadian geologist, for it is recorded that he made an examination of a collection of fossils from Canada in 1752 and on the evidence thus secured attempted to make a subdivision of the rocks of the New World.

The seeds planted by Guettard were long in germinating, but they bore fruit about the year 1790. The three decades following that date have been called by Zittel the "Heroic Age in Geology." During this thirty years the new ideas crystallized, speculation was discountenanced, fossils assumed an historical importance, and the actual determination of the sequence and subdivisions of strata replaced the previously popular "Theories of the Earth."

During this period arose modern stratigraphic geology with the distinct recognition of the value of fossils as time-markers. The contemporaneous labour of William Smith in England and of Cuvier and Brongniart in France laid the foundation of Historical Geology and has led to the recognition of these men as the fathers of the science. Smith's famous map of England was published in 1815 and his scanty publications continued to 1820, the close of the Heroic Age.

This period of struggle between the old and the new ideas was not a time of complete victory for the latter. Imagination did not yield entirely to deductions from observed fact. Theories of the Earth still appeared and even the great Cuvier's *Catastrophal Theory* betrays the dominating influence of the older literature.

The older tendencies were apparent, also, in generalization from insufficient data: the outstanding example of this is Werner's neptunism. This distinguished man lived until 1817 without relinquishing or modifying in the slightest degree his conception of the earth's crust. The great exponent of vulcanism, James Hutton, betrays also a lingering remnant of the old point of view in the very title of his famous work, "Theory of the Earth," which appeared in 1785 and was followed in 1802 by the elegant "Illustrations of the Huttonian Theory" from the pen of his friend and admirer, Playfair.

Another significant feature of the Heroic Age was the recognition of the necessity for wider observation, which was strikingly illustrated by the lives of the great geological travellers, Pallas (1741-1811) and von Humboldt (1769-1859), and by the pioneer alpinist, de Saussure (1740-1799).

Notwithstanding the able work of Hutton and his adherents this famous thirty years of regeneration was distinctly Wernerian as indicated by the text-books of the time—Reuss, Leipzig, 1800-1806; Jameson, Edinburgh, 1808; De Bonnard and De Voisins, France, 1819.

In North America, geology had its origin during the Heroic Age. It is significant that Merrill selects an almost synchronous time, 1775-1819, as the first period of American geology, to which he gives the name "Maclurean Era." This era opens with the new light breaking but obscured by the clouds of the vulcanist-neptunist controversy. It was essentially Wernerian. Maclure's famous map was published in 1809 and the second edition of his "Observations" in 1817, both purely Wernerian. It would seem that no publication dealing with Canadian geology appeared during this period, *i.e.*, up to 1820.

Period 1820-1840

The two decades, 1820-1840, constitute the "University Period" in the development of our subject: it is given a recognized position in the great universities of Europe: it is at last a "science." Consequent upon this recognition came subdivision and specialization: the general geologist, even at this early time, began to give way to the specialist. Cosmic, dynamic, stratigraphic, and other phases of geology received independent positions, and palaeontology rose to the rank of a distinct science. The term, *palaeontology*, was proposed in 1834 by two independent workers, De Blainville and Fischer von Waldheim.

Early in this period the importance of stratigraphy and the value of fossils in chronology is emphasized in "The Geology of England and Wales" by Conybeare and Phillips. It is to be noted, however, that the old ideas died hard, for Bakewell's "Introduction to Geology," while not purely Wernerian, savours largely of that school, and the last edition, issued in 1838, disregards entirely the work of Smith and discountenances the use of fossils for the determination of horizons. The second American edition of this work, published in 1833, attributes the stratigraphic column with its entombed organic remains to Noah's deluge.

During this period, as we have seen, stratigraphic geology and its twin sister, palaeontology, have become differentiated and henceforth are to be regarded as more or less distinct branches of the science. The concentration of effort thus attained bore wonderful fruit: Sedgwick announced the Cambrian system in 1836, Murchison created the Silurian in 1839, and these two distinguished stratigraphers working together unravelled the Devonian system in 1839. The problem of the "Transition" rocks was at last solved, although many years elapsed before full recognition was given to the labours of these two great pioneers.

Significant of this period was the appointment of Wm. Buckland as first professor of geology at Oxford and the establishment of the Geological Survey of the United Kingdom under de la Beche in 1835. While the fame of Sir Charles Lyell (1797-1875) will forever rest chiefly on his announcement of the doctrine of "uniformitarianism," it must not be forgotten, from the present point of view, that he proposed in 1832 to divide the Tertiary into Eocene, Miocene, and Pliocene.

The second period of American geology begins about 1820. Merrill has called the first half (1820-1829) of the period we are considering the "Eatonian Era." It is characterized by the first serious attempts to correlate American strata by means of fossils and by efforts towards the establishment of state surveys.

The second decade (1830-1840) is termed by Merrill the "First Decade of the Era of State Surveys." During this time geological investigations under government control were carried on in Massachusetts, Tennessee, Maine, Connecticut, New Jersey, Maryland, Delaware, Ohio, Michigan, Indiana, Georgia, and North and South Carolina. It is worthy of note, also, that Nicollet carried geological investigation west of the Mississippi river.

This survey of the development of geological science has been necessary in order to realize the conditions under which the earlier contributions to Canadian geology appeared. In 1823 Dr. J. J. Bigsby, Secretary to the Boundary Commission under the Treaty of Ghent, published "Notes on the Geology and Geography of Lake Huron."

In 1828 there appeared in the American Journal of Science an account of Nova Scotian geology, entitled "The Geology and Mineralogy of the northern parts of Nova Scotia," by two Americans, C. T. Jackson and Francis Alger. The conception of stratigraphy indicated by this work is largely Wernerian, but the authors admit somewhat reluctantly that they are obliged "to allow the superiority of the igneous theory of Hutton, Playfair and Daubenay." It is significant also that the granite was regarded as older than the slate because it contained no fossils: its igneous origin was not recognized as in the case of the traps.

In 1836 Abraham Gesner published "Remarks on the Geology and Mineralogy of Nova Scotia." This book of 272 pages reveals clearly the geological thought of the time. The doctrine is catastrophic in the extreme, and the phraseology Wernerian. Fossils are seriously regarded as time-markers and their resemblance to living forms noted. The reader is warned, however, "that their lineal descendants have long since passed away," thus disclaiming any thought of genetic connection. Movements of the rocks are discussed and Noah's deluge held responsible for the existence of the strata and their contained organisms. Volcanic activity is admitted, even glacial boulders being ascribed to volcanic explosions subsequent to the general inundation.

Gesner was appointed Provincial Geologist of New Brunswick in 1838, and, as we shall see later, made important contributions to the geology of that province. He founded the Gesner museum in St. John which afterwards became the property of the Natural History Society of New Brunswick.

During this period (1820-1840) appeared also a number of fragmentary papers by Captain Bonnycastle, Lieutenant Baddesley, and others, a complete list of which may be found in Harrington's "Life of Sir William Logan."

Of great importance in its subsequent effect on Canadian stratigraphic geology was the founding of the Geological Survey of the State of New York in 1836. The state was divided into four districts which were entrusted severally to the four distinguished pioneers, Hall, Emmons, Mather, and Vanuxem.

Hall's "Report on the Fourth District" appeared in 1843. Formational names still in use were introduced but there was little attempt to correlate the strata with those of Europe. Hall's table of formations is so important in its bearing on Canada that it is given in outline on page 5.

HALL'S CLASSIFICATION OF AMERICAN STRATA

Quaternary System	
Tertiary System	
New Red Sandstone	
Carboniferous System	
Old Red System or Old Red Sandstone	
New York System	Erie Division Helderberg Series Ontario Division Champlain Division

The New York system and its divisions have disappeared from the literature but most of the numerous formations into which the divisions were subdivided are still retained.

The reports of Vanuxem, Mather, and Emmons are for the most part in accord with that of Hall except for the introduction below the New York system of another called the *Taconic.* This difference of opinion developed later into quite a celebrated controversy, the "Taconic Question."

In considering these New York reports in the period under consideration (1820-1840) we have gone slightly beyond our time limit, but it must be remembered that the work was inaugurated in 1836 and began to exert an influence before the date of publication. About 1840, therefore, we have in North America a lingering of Wernerism, a growing local classification, a catastrophic philosophy, a fixed conviction of the value of fossils for the determination of horizons, and a recognition of the value of state-aided geological surveys. In Canada, as we have seen, very little geological work had been done and except in a few isolated areas the country was *terra incognita* geologically.

Period 1840-1870

The first attempts to establish a geological survey of the provinces began in 1832 but it was not until 1841 that these efforts bore fruit. In that year a grant of £1,500 was made for the purpose and Mr. William Edmond Logan, on the recommendation of Sedgwick, Murchison, Buckland, and de la Beche, was charged with the modest task of preparing a Geological Report on the Province of Canada. The actual work of the Survey began in 1843 but Logan's first report bears the date September 6, 1842, and his last May 1, 1869. These three decades 1840-1870 may well be regarded as the "Loganian Period" of Canadian geology.

Logan, as he himself says, was a stratigraphic geologist, but he was also a wise man, and knowing the source of funds for the prosecution of the work, he never lost sight of the economic aspect of the subject. He entered on his duties under the influence of his distinguished sponsors at the time the Cambrian-Silurian controversy was beginning, a controversy which became more complicated by the introduction of the Taconic Question and which had scarcely died away when his term of office expired. Murchison's *Siluria* appeared in 1854 and was followed by Sedgwick's rejoinder in 1855. After this date "Cambrian" was officially ruled out, but Sedgwick continued to support his convictions until his death in 1873.

Logan seems to have adopted Murchison's view, for the word "Cambrian" does not appear in his reports and "Taconic" is likewise conspicuous by its absence. With Hall and Dana he remained obstinate as to the identity of the Taconic rocks with the Champlain or lowest division of the New York system.

De Verneuil in 1846 made the first serious attempt to correlate the rocks of America with those of Europe and established for America the boundaries of the Silurian and Devonian systems. Logan continued to use the New York nomenclature until 1852 when he introduced the European terms. The report of 1863, which does not differ from Logan's latest reports, gives the following as the major divisions of geological time as revealed in Eastern Canada—Carboniferous, Devonian, Upper Silurian, Middle Silurian, Lower Silurian, Azoic.

Logan was the father of Canadian geology. Tireless, self-sacrificing, enthusiastic, he gathered around himself a small body of loyal and efficient assistants; forceful, prudent, yet pliable, he was able to guide the infant Survey through many shoals of governmental non-support. His first assistant was Alexander Murray, a trained geologist appointed in 1842. The following year he worked in co-operation with Dr. William Dawson, then only 23 years of age, but who afterwards played so important a part in Canadian geology. Logan's other field assistants were not numerous; James Richardson, a farmer, was appointed in 1856, Robert Bell a civil engineer in 1857, and later G. Vennor, Charles Robb, and Edward Hartley.

It is not the purpose of the present paper to speak of the work accomplished by Logan and his assistants in the field of stratigraphic geology. That work is monumental and familiar to you all. It will suffice to state that practically all the stratified rocks from Manitoulin island to the coast were examined in greater or less detail and assigned to a place in the stratigraphic column.

Logan at the very beginning of his work felt the great necessity for palaeontological assistance and appealed to de la Beche for help: this was readily accorded, with the result that the names of Owen, Salter, Jones and other British palaeontologists appear in the records of the Survey. In 1844 Logan visited Hall and Emmons at Albany and felt, in consequence, a still greater desire for the services of a palaeontologist, but this desire was not satisfied until 1856 when Elkanah Billings was added to the staff of the Survey as palaeontologist.

Billings was our first palaeontologist and he has every right to be regarded as the father of this branch of the science in Canada. During his period of service, until his death in 1876, he published about one hundred and seventy separate papers, ninety-three of which appeared in the Canadian Naturalist and Geologist which he himself founded in 1856. Billings is credited with the description of sixty-one genera and one thousand and sixty-five species of Canadian Palaeozoic fossils; he did much to unravel the complicated stratigraphy of the Quebec group, and came to the support of Emmons with regard to the Taconic Controversy.

It is now necessary to review briefly the advances made by geologists outside the Geological Survey of Canada during this period of thirty years, 1840-1870. The name of Sir Wm. Dawson is of outstanding importance and must stand side by side with that of Logan. Dawson, then a young man of 23 years, was working on geological problems in Nova Scotia when Logan began his first survey and he was with Lyell when that distinguished geologist made a trip through the province in 1842. In 1855 Dawson was made Principal and Professor of Geology at McGill. Of his services to that institution and to education in general it is unnecessary to speak. His contributions to science were many and varied: prior to 1870 alone he produced about two hundred separate articles. Acadian stratigraphic geology owes much to his efforts as the three editions of "Acadian Geology" attest. Dawson is perhaps best known for the monumental work on Silurian, Devonian, and Carboniferous plants, and for his discovery of amphibians in the Palaeozoic Together with that of Logan his name will always be associated with the pseudo-organism *Eozoon canadense,* which name was given by Dawson in 1864.

Besides his actual contributions Dawson did much for geology in Canada by his close association with the distinguished workers in

Europe. He was a constant friend and admirer of Lyell, to whom his "Acadian Geology" was dedicated.

Acadian geology also owes much to the labours of other pioneers during this early period. Dr. Abraham Gesner submitted five reports to the Legislature of New Brunswick on the geology of the province between the years 1839 and 1843. Dr. James Robb published a map of New Brunswick with observations in 1850. Dr. G. F. Matthew, whose name has subsequently become so closely connected with the Cambrian of Eastern Canada, began his work on the rocks at St. John in 1851, and in 1863 published a revision of Dawson's subdivisions. Dr. Bailey worked on the Tobique and Nipisiguit rivers in 1864 and with Matthew and Hartt in 1865. An important result of this joint work was the announcement of a "Primordial Fauna at the base of the St. John group representing a Silurian Horizon lower than any previously determined."

The stratigraphic succession, as recognized in the maritime provinces in 1870, is given by Matthew and Bailey as follows:—

MATTHEW AND BAILEY'S TABLE OF 1870

Triassic or New Red Sandstone
Carboniferous or Coal Measures
Lower Carboniferous
Perry Group
Granite
Devonian
Upper Silurian
Lower Silurian or St. John Group
Huronian
Laurentian

In connection with the work in the maritime provinces during this period, mention should also be made of the work of Gesner in Cape Breton in 1846, of Rev. Dr. Honeyman at Arisaig, and of Mr. R. Brown, also of the assistance of the great vertebrate palaeontologists, Owen and Marsh.

It is now necessary to glance briefly at the beginnings of geological explorations in the prairie regions of the West and it is again to the south of the boundary that we must go for the initiation of the accepted nomenclature.

In 1804-05-06 Lewis and Clarke conducted an expedition to the source of the Missouri and across to the Columbia; subsequently Nuttall and Long brought fossils from that region which were recognized as Cretaceous. In 1832 the Prince of Nieuwied discovered the first Cretaceous reptilian remains at Great Bend below Fort Pierre. In 1839 the geographer Nicollet ascended the Missouri to Fort Pierre, collected fossils, and subdivided the strata. In 1849 Dr. John Evans made a trip into the bad lands on the White river of Nebraska and collected many fossils which were described and figured by Owen in his report of 1852.

Meek and Hayden were in the bad lands in 1853: they divided the strata into five formations ascribed without names to the Cretaceous and Tertiary. The fossils collected were described in a Memoir of the American Academy of Arts and Sciences, Boston, 1856. This classification was extended and published, with names, by the same authors in the Proceedings of the Academy of Natural Science of Philadelphia in 1861. The Cretaceous was divided into Dakota, Fort Benton, Niobrara, Fort Pierre, and Fox Hill.

Turning now to Western Canada we find that a great amount of geographical exploration preceded definite work in stratigraphy; nevertheless many of the records of these early explorations contain references of geological significance. The following brief notes indicate the general trend of investigation: 1739—Verendrye discovered Lake Manitoba. 1750—M. Legardeur de Saint Pierre ascended the Saskatchewan. 1792—Fiddler went through to the mountains and reported coal at the junction of Rosebud creek with the Red Deer river. 1797—David Thompson crossed to the Pacific. 1799-1804—Alexander Henry was in the eastern prairie region. 1814—Franchère passed through the Yellowhead pass. 1825—Thomas Drummond of the Second Franklin Expedition led a party to Edmonton. 1841—Sir George Simpson sent coal from Edmonton to Sir Wm. Logan. 1845-58—The first definite geology was worked out by Dr. Hector of Palliser's expedition. He recognized Cretaceous and Tertiary rocks, also the occurrence of coal. Hector's report appeared in 1861 in the Journal of the Geological Society, Vol. 17. 1858—S. S. Dawson collected fossils which were sent to Billings. His report contains a letter from Billings together with others from Meek, Hayden, Sir Wm. Dawson, and Jones, confirming the occurrence of Cretaceous rocks in the Canadian North-West. 1858—H. Y. Hind recorded the occurrence of Devonian rocks on Lake Manitoba.

Nothing further seems to have been done in this region until the close of the period we are considering in 1870.

Period 1870-1900

It is somewhat difficult to subdivide the time from 1870 to the present into periods separated by events of outstanding importance. We may, however, regard the thirty years from 1870 to the end of the century as a convenient period for description. These years mark the terms of office of Dr. A. R. C. Selwyn and Dr. G. M. Dawson as Directors of the Geological Survey of Canada. Within the Survey the period is marked particularly by investigations of two distinct kinds:—reconnaissance work far afield, and the detailed quarter-sheet survey of the eastern part of the country. One is tempted to call the period either the "Reconnaissance" or the "Quarter-sheet Epoch" in Canadian geology. Outside the Survey stratigraphic geology is chiefly indebted to the continued labours of Sir Wm. Dawson, Dr. Geo. F. Matthew, Dr. L. W. Bailey, Professor Nicholson, Dr. George Jennings Hinde, and Dr. H. S. Scudder.

With regard to the work in Eastern Canada it may be said that during this period a re-survey in detail was made from the Pre-Cambrian boundary in eastern Ontario to the coast. It is quite beyond the scope of this paper to attempt a description of a work of this magnitude. It will suffice to connect with the earlier efforts the names of L. W. Bailey, G. F. Matthew, H. G. Vennor, and C. Robb, and for the latter part of the period to add the names of R. W. Ells, Hugh Fletcher, E. R. Faribault, and Monseigneur Laflamme. The net result of this work was the production of a magnificent series of detailed maps and great additions to our knowledge of the tectonic geology of the region.

With regard to the major stratigraphic terms we find the word "Cambrian" used by Dr. Selwyn in 1877 and "Ordovician" by Dr. Matthew in 1894. The chief advances in detailed stratigraphy were due to Dr. Matthew's labours on the Cambrian and to a less extent on other Palaeozoic formations. About the year 1900 he advocated a systemic value for the lowest fossiliferous formation, the Etcheminian, and a division of the Cambrian into only two subdivisions, an upper and a lower. This view was strongly opposed by Dr. Charles D. Walcott, who favoured the inclusion of the Etcheminian in the Cambrian and a division of the system into three series. The resulting discussion marked the close of the period we are considering.[1]

During this time the stratigraphy of eastern Ontario was worked out in greater detail but no additions were made to the nomenclature of 1863. It is significant that southwestern Ontario was entirely neglected throughout the whole of this period.

We must turn now to the great reconnaissance work undertaken by the Survey in the vast regions to the north and west of the old Provinces of Canada—a territory brought into the Dominion by

[1]Proc. Washington Acad. Sci., Vol. I, 1900, pp. 301-339.

Confederation which practically corresponds with the beginning of the period we are considering. Omitting all references to Pre-Cambrian geology, to which a large measure of the Survey's efforts was directed, we find at once a renewal, or perhaps the real beginning, of geological activity in the west. It seems advisable to consider separately the region of the great plains and of the cordillera.

The Region of the Great Plains

The prairie country was practically unknown geologically in 1870: we have already reviewed the sparse literature available. On assuming the office of Director, one of Dr. Selwyn's first explorations consisted of a trip to Fort Garry and thence to the Rockies. Dr. G. M. Dawson traversed practically the same country as botanist and geologist to the North American Boundary Commission in 1873. His report, "The Geology and Resources of the 49th Parallel," was published in 1875 and contains the first recognition in Canada of Meek and Hayden's classification. He uses the term "Lignitic Tertiary Formations" for the northward extension of the Fort Union. In Dr. Dawson's report on the Region of the Bow and Belly Rivers, contained in the Annual Report of the Geological Survey for 1882-84, the following stratigraphic column appears:—

DR. DAWSON'S TABLE OF WESTERN STRATA

Laramie:	Porcupine Hill beds
	Willow Creek beds
	St. Mary River beds
Cretaceous:	Fox Hill
	Pierre
	Belly River
	Lower Dark shales

In 1874 Dr. Robert Bell traversed a section of country farther north—from Fort Garry to Fort Pelly—and brought back evidence of the occurrence of Niobrara strata. He also noted Devonian on Lake Winnipeg and Cretaceous at other points.

At about the same time that Dawson applied the Meek and Hayden classification to the rocks of southern Alberta, McConnell was in the Cypress hills of southern Saskatchewan and records the first definite subdivision of Tertiary strata as shown in the following table:

McCONNELL'S TABLE OF WESTERN STRATA

Tertiary:	Pliocene(?) Saskatchewan gravels
	Miocene
Cretaceous:	Fox Hill
	Pierre
	Belly River
	Lower Dark shales

McConnell's report records the first discovery of fossil vertebrates in western Canada.

During the years 1884-86 Mr. J. B. Tyrrell carried on extensive exploration in northern Alberta and added the terms "Paskapoo" and "Edmonton" to the stratigraphic column, as subdivisions of the Laramie. The Paskapoo was made to embrace Dawson's Porcupine Hill and Willow Creek series and most of his St. Mary River beds. Later Tyrrell worked out the stratigraphy of the Duck and Riding mountains and did extensive and important work in Northwest Manitoba. He divided the Pierre into two series—the Millwood and Odanah—recognized the Niagara age of the Silurian and subdivided the Devonian into Upper Devonian or Manitoban, Middle Devonian or Winnipegosan, and Lower Devonian. Tyrrell made very extensive collections of fossils, which subsequently proved of great value in the hands of Dr. Whiteaves.

Tyrrell together with Dowling carried the classification into the region of the Athabaska and Churchill rivers. They recognized Devonian rocks in this area and the occurrence of the Athabaska sandstone which they ascribed to the Cambrian (Keweenawan). The Cretaceous strata were classified as follows:—

TYRRELL AND DOWLING'S CLASSIFICATION OF NORTHERN CRETACEOUS

Dark shales—Pierre
Calcareous shales—Niobrara-Benton
Incoherent sandstones—Dakota

The next development of importance was the classification of the Palaeozoic rocks of Manitoba by Dowling. His report gives great credit to Professor Panton and Mr. A. McCharles for previous work and for the collecting of fossils. Dowling draws a close comparison with the Minnesota section and gives the following table of classification:—

DOWLING'S TABLE OF MANITOBA PALAEOZOICS

Stony Mountain		
Utica		
Trenton	Upper Mottled limestone Cat Head limestone Lower Mottled limestone	
Black River (?)	Winnipeg sandstones and shales	

Tyrrell and Dowling at a later date worked in northern Saskatchewan and on the Athabaska extending northward the classification now established. Towards the close of our period McConnell was on the Mackenzie, Yukon, Peace, and Liard rivers and Great Slave lake. He recognized Cambro-Silurian on the Liard and Mackenzie, also Devonian with many fossils, recorded Triassic on the Liard and the occurrence of Cretaceous and Tertiary strata at a number of points. A very instructive table accompanies McConnell's report; it is reproduced in full below:—

MCCONNELL'S TABLE OF FORMATIONS ON THE ATHABASKA AND PEACE RIVERS

Athabaska River		Peace River
Laramie	Laramie	Wapita River sandstone
Fox Hill sandstones La Biche shales	Montana	Fox Hill Smoky River shales Dunvegan sandstone
La Biche shales Pelican sandstone Grand Rapids sandstone Clearwater shale	Colorado	Fort St. John shales Peace River sandstone Loon River shales
Tar sands	Dakota	

The Cordilleran Region

In our account of the period prior to 1870 scarcely any mention was made of stratigraphic work in British Columbia and very little seems to have been done. We find, however, that a certain amount of investigation had been carried on by Bauerman, Hector, Forbes, and Robert Brown. In 1871 Dr. Selwyn, accompanied by James Richardson, was in the Pacific province and gave the following first stratigraphic column:—

SELWYN'S TABLE OF BRITISH COLUMBIA STRATA

I.	Superficial.
II.	Volcanic Series and Coal and Lignite Group of Mainland; Coal Rocks of Vancouver Island.
III.	Jackass Mountain Conglomerate Group.
IV.	Upper Cache Creek Group (Marble Canyon Limestone).
V.	Lower Cache Creek Group.
VI.	Anderson River and Boston Bar Group and Upper Rocks of Leather Pass and Moose Lake.
VII.	Cascade Mountain and Vancouver Island Crystalline Series.
VIII.	Granite, Gneiss, and Mica Schist.

Having extended his observations farther to the north, Selwyn in his report for 1875-76 adopts the same basis of classification but brings the formations into the accepted time scale as below:—

SELWYN'S TABLE OF NORTHERN BRITISH COLUMBIA STRATA

I.	Cainozoic—Superficial and Lignite Tertiary including the Upper Volcanic Series.
II.	Mesozoic—Cretaceous Coal-bearing Rocks.
III.	(?)—Sandstone, shales, and conglomerates of Foothills.
IV.	Palaeozoic—Upper and Lower Cascade Groups.
V.	Granite and Mica Schist.

About the same time Dr. G. M. Dawson conducted his first expedition into British Columbia: he employed Selwyn's nomenclature but established the Carboniferous age of the Cache Creek Group. In a later report (1877-78) he brought the crystalline series of Vancouver island into the Cretaceous and proved by fossils a similar age for the Jackass Mountain series.

The following year we find a voluminous report by Dawson on the Queen Charlotte Islands: the stratigraphic column is divided into Post-Pliocene, Tertiary (probably Miocene), Cretaceous, Triassic.

The next important development is the correlation of the Cretaceous rocks of the mountains with those of the foothills and plains, which appeared in his report for 1885 as follows:—

DAWSON'S CORRELATION OF CRETACEOUS STRATA

Rocky Mountains	Foothills and Plains
	Porcupine Hill
	Willow Creek
St. Mary River beds	St. Mary River beds
Fox Hill and Pierre	Fox Hill and Pierre
Belly River series	Belly River series
Benton and Niobrara	Lower Dark shales
Volcanic rocks	
Dakota and upper part of Kootenay	
Lower part of Kootenay	

This same report contains also great additions to our knowledge of the Palaeozoic section. Eleven thousand feet of Cambrian are followed by the great series of Devono-Carboniferous limestones and shales, above which are rocks ascribed to Triassic or Permo-Triassic age.

The following year appeared McConnell's stratigraphy of the mountains, which has remained to this day the basis of nomenclature.

MCCONNELL'S STRATIGRAPHY OF THE ROCKY MOUNTAINS

Cretaceous	Kootenay to Benton
Carboniferous passing downwards into Devonian	Upper Banff shales
	Upper Banff limestone
	Lower Banff shales
	Lower Banff limestone
Devonian	Intermediate limestone
Silurian	Halysites beds
Cambro-Silurian	Graptolitic shales
	Upper part of Castle Mountain group
Cambrian	Lower part of Castle Mountain group
	Bow River group

Another advance made in this year was the correlation by Dawson of the rocks of Vancouver and adjacent islands with those of Queen Charlotte island.

It may be said, therefore, that about 1886 the main framework of the classification of the rocks of British Columbia was established. We may pass over the details of the following fifteen years during which much was added to the areal geology of the cordilleran region but little of outstanding importance to the general stratigraphic subdivision. In this connection a tribute should be paid to the continued labours of Dawson and McConnell and to the work of James McEvoy and R. W. Brock.

Palaeontology 1870-1900

The great amount of exploration carried on by the Survey in regions of sedimentary rocks naturally resulted in large collections of fossils, the determination of which was of first importance in working out the stratigraphy. With the exception of Sir Wm. Dawson and Dr. Geo. F. Matthew, the distinguished workers whose names have been mentioned were not palaeontologists; in consequence, the work of identification fell on the palaeontologists of the Survey—at first Billings and afterwards Dr. Whiteaves, Dr. H. M. Ami, and Mr. Lawrence M. Lambe.

Billings' fame rests on his work on the Palaeozoic fossils of eastern Canada which we have already reviewed. His last publication, in 1876, reaches but a short time into the period we are considering; nevertheless, the extended scope of the Survey is indicated by some of his later papers, as: "List of Devonian Fossils from the Assiniboine river and Lake Winnipegosis," "Note on Fossils from Ballinac islands, British Columbia," "On Mesozoic Fossils from British Columbia collected by Mr. James Richardson in 1872," "Fossils found in Lower Cache Creek, British Columbia."

Dr. J. F. Whiteaves succeeded Billings as palaeontologist to the Survey in 1876 and upon him fell chiefly the onerous duty of identifying and describing fossils from all horizons and all parts of the country. The volumes of the Survey attest his success. His work ranged from Protozoa to Fishes, from Cambrian to Post-Glacial, from the Atlantic to the Pacific, and into the islands of the far north. Dr. Whiteaves contributed about one hundred and fifty separate papers or reports and lived but a short time into the present century (1909). His work is characterized by great caution and is very dependable: he could never be induced to offer an opinion on material which he considered too fragmentary for certainty.

Mr. Arthur H. Foord joined the staff of the Survey as artist about 1872 and was afterwards made Assistant Palaeontologist; he resigned in 1884. Foord's chief work was his contribution to the Micro-palaeontology of the Cambro-Silurian rocks of Canada.

Dr. H. M. Ami was appointed second Assistant Palaeontologist on July 1st, 1884. Between the years 1882 and 1901 he published two hundred and seven articles, many of which deal with palaeontological subjects, including descriptions of new species and long lists of fossils identified from various horizons and localities for different officers of the Survey.

In addition to the work of the regular officers of the Survey there must be added important contributions made from time to time by experts in particular branches of palaeontology, among which may be mentioned:—

H. S. Scudder —Several articles on Tertiary Insects of British Columbia, 1875-1878.
Canadian Fossil Insects, Myriopods, and Arachnids, 1895.
Canadian Fossil Insects, 1900.
D. H. Penhallow—Fossil Plants from the Plesistocene, etc., 1899.
Sir Wm. Dawson—Many important contributions to the records of the Geological Survey.

It is impossible to close this record without reference to the veteran collector, T. C. Weston, whose work in eastern Canada and Newfoundland did much to advance the cause of palaeontology. In later years Mr. Weston was one of the pioneers in vertebrate collecting in the west.

The Survey's first effort in the direction of Vertebrate Palaeontology was the appointment of E. D. Cope as Honorary Vertebrate Palaeontologist following McConnell's discovery of mammalian remains in the Cypress hills. Cope's direct contributions to the Survey's publications were; "The Vertebrata of the Swift Current Creek region of the Cypress hills," 1885; and "On Vertebrata from the Tertiary and Cretaceous rocks of the North West Territory," 1891. At the time of his death in 1897 Cope had a collection of Cretaceous vertebrates from Canada in his possession. These were returned to Ottawa and were placed in the care of Mr. Lawrence Lambe, then working under the direction of Dr. Fairfield Osborne, who followed Cope for a short time as Honorary Vertebrate Palaeontologist to the Survey.

Lawrence M. Lambe's first scientific paper appeared in 1892; it dealt with a zoological subject. His first palaeontological paper was published in 1896, and his first effort in Vertebrate palaeontology in

1898. We shall have occasion to refer to Lambe's work later, as the bulk of his publications belong to a subsequent period. For the present we may be permitted to transgress two years beyond 1900 in order to speak briefly of the first work dealing with the dinosaurs of the Cretaceous by a Canadian writer.

The first detailed reference to dinosaurian remains in Canada is contained in an Appendix by Cope to Dr. G. M. Dawson's report on the 49th Parallel, 1875. Later Cope described in the Proceedings of the American Philosophical Society two skulls of *Laelaps incrassatus*, one obtained by J. B. Tyrrell in 1884 and the other by T. C. Weston in 1889. Lambe made collecting trips in the valley of the Red Deer river in 1897, 1898, and 1901. The results of his work appear in Volume III, Part II, of Contributions to Canadian Palaeontology.

Development Other than in the Geological Survey of Canada, 1870-1900.

Stratigraphic investigation during this period was practically confined to the work of Sir Wm. Dawson, Dr. Geo. F. Matthew, and Dr. Bailey, and their efforts were more or less connected with the activities of the Survey.

The work of Sir Wm. Dawson prior to 1870 we have already referred to: it is significant that his death occurred on Nov. 18, 1899, thus marking the close of the period we are considering. During these thirty years his productions were voluminous and his influence extraordinarily potent. He gave to McGill University a predominance in matters scientific and made it the training ground for Canadian geologists. It is remarkable that Sir William left no successor at McGill with a leaning to the stratigraphic side of geology and to palaeontology. The reason for this probably lies in the undue accentuation of Pre-Cambrian Geology and the worship of the petrographic microscope that marked the close of the century. A striking characteristic of Sir William was his life-long opposition to the doctrine of evolution. Several of his papers deal with the subject; after recognizing the merit of certain of Darwin's statements, he adds: "All these facts are not the less valuable to the judicious reader that the author has seen fit to string them upon a thread of loose and faulty argument, and to employ them to deck the faded form of the transmutation theory of Lamarck;" and later, "We have seen the able review of Mr. Darwin's work made by Professor Gray and Professor Huxley. Both naturalists dissent from his conclusions as not satisfactorily proved, though neither, in our view, insists sufficiently on the fundamental unsoundness of the argument."

In this connection it is worthy of note that "The Origin of Species" appeared in 1859 and that Asa Gray, the botanist, was one of the first Americans to endorse Darwin's views. The result was soon seen in palaeontology in the work of Alpheus Hyatt and Beecher. There seems to have been little or no response to the new ideas on the part of Billings or Whiteaves: on the other hand, Matthew accepted evolution with alacrity. In a recent letter to the writer, Dr. Matthew states, "I was an evolutionist before I saw any of Darwin's books. See my article *re* development of the trilobites sent to the Malacological Society of Belgium, or later, the article on the trilobites of Long Island, Kennebecasis river."

Henry Alleyne Nicholson was Professor of Natural History in the University of Toronto in the early Seventies. He was essentially a palaeontologist and his outstanding Canadian work is the "Report on the Palaeontology of the Province of Ontario," which appeared in two parts, the letter of transmittal of the first dated Toronto, October, 1873, and of the second, Newcastle-on-Tyne, October, 1874. Nicholson also contributed to scientific journals several papers dealing with Canadian and American palaeontology.

With Nicholson worked Dr. George J. Hinde, who later became the great English authority on fossil sponges. His chief Canadian work was the description of the conodonts and annelid teeth from the Ordovician strata of Toronto.

After Hinde and Nicholson stratigraphic geology and palaeontology fell to a position of slight relative importance at Toronto. Professor E. J. Chapman, who followed Nicholson as Professor of Geology and Mineralogy, was essentially a mineralogist, assayer, and economic geologist. His publications were largely mineralogical and economic, but he was also the author of certain text-books dealing with stratigraphic geology. In palaeontology he will be remembered chiefly as the discoverer of *Ogygites canadensis*, now regarded as the type fossil of the Collingwood formation. Professor Chapman retired at an advanced age in 1895.

During part of the period under review Professor James Fowler was Professor of Natural History at Queen's University and was charged with the teaching of geology: he was essentially a botanist and not greatly interested in the subject of stratigraphy. The School of Mines was established in 1893 with W. G. Miller, first as lecturer in, and afterwards, Professor of Geology. Dr. Miller's interest has been directed more particularly towards economic and Pre-Cambrian geology.

General interest in stratigraphy and palaeontology in Ontario was not great during these thirty years. We look in vain for many published advances in the science. Undoubtedly the greatest credit is due to Dr. J. W. Spencer, whose first contribution under the title "Geological Sketches in the Neighbourhood of Hamilton" appeared in the Canadian Naturalist for 1875. This was followed by a number of papers on various phases of geology, chiefly glacial. The "Graptolites of the Niagara Formation" and "Palaeozoic Geology of the Region about the Western End of Lake Ontario" were his chief contributions to the subjects we are considering.

While it is impossible to do justice to all those who aided the cause by local collecting and by submitting material to experts for description, the following names are particularly well-known:—

Mr. J. E. Narraway and Mr. W. R. Billings at Ottawa; Colonel Petitt at Grimsby, Ont.; Mr. G. Kernahan, Rev. Hector Currie, and Mr. N. J. Kearney on the Hamilton formation in Lambton county; Colonel C. C. Grant, Mr. A. E. Walker, Mr. B. E. Walker, at Hamilton; Dr. David Boyle and Mr. Joseph Townsend on the Guelph formation and the latter also on the Cincinnatian of the Toronto district.

Mr. B. E. Walker, afterwards Sir Edmund Walker, was deeply interested in palaeontology; he added largely to the local collection made by his father and also acquired extensive collections from all parts of the world. About the close of our period Sir Edmund presented to the University of Toronto all of his collections together with a valuable palaeontological library. These fossils and books formed the nucleus of the present Royal Ontario Museum of Palaeontology and of the library connected therewith.

Period 1900 to Present

The period from 1900 to the present may be regarded as marked by an increasing degree of specialization within the Survey and by an added interest in Canadian geology on the part of workers from across the line. The general geologist is gradually being replaced by the stratigrapher—the stratigrapher sufficiently versed in palaeontology to require only in special cases the advice and assistance of the pure palaeontologist. The writer does not wish to imply that this type of man did not exist before—there are outstanding examples to the contrary—but in his opinion, the general recognition of the palaeontologically trained stratigrapher is the striking feature in the history of stratigraphic geology in Canada during the past twenty years, perhaps it would be better to say the past ten years.

Outside the Government Service we have little reason to be proud of the achievements of Canadians in our subject. The enthusiasm for local collecting has practically died out and little has been done to incite public interest in stratigraphy. The fault must lie in our educational system; but the whole subject, while of vital importance, does not come within the scope of this address.

The history of the past twenty years deals so intimately with the achievements of the writer's immediate contemporaries that he must be pardoned for a very sketchy review without any pretension of doing justice to the many workers in the field.

We start the period with the framework of the stratigraphic column fairly well established over the whole of accessible Canada and with a considerable degree of detail in parts, particularly in the east. It is proposed to record the more important advances made under the following geographic subdivisions: Maritime Provinces, Quebec, Older Ontario, Hudson Bay Slope, The Great Plains, The Cordillera.

Maritime Provinces

We have to record in the first place the continued labours of the veterans, Matthew and Bailey, of Ells and of Fletcher. The two former are still with us; but the latter two were permitted to live and work scarcely through the first decade of the century. Dr. E. R. Faribault belongs to both periods; his work in Nova Scotia extends from 1885 to the present day and his name will be forever associated with the geology of the gold-bearing rocks of Nova Scotia.

The later generation of geologists of the Maritime Provinces may be said to begin with Dr. G. A. Young, whose first report for the Survey, a description of the Lake St. John district, appeared in 1900. Later Dr. Young did much work in New Brunswick, chiefly of an economic nature.

We have now to deal with a policy and its results—the opportunity offered by the Survey to graduate students to acquire materials for theses. The policy itself requires no explanation and is highly commendable; the only unfortunate feature is that nearly all the students thus favoured were proceeding to degrees in American universities. We are more concerned with the results which are important additions to the detailed stratigraphy of selected areas. Perhaps Dr. M. Y. Williams may be considered the first of this class of workers; he was engaged in studying the famous Silurian section at Arisaig, N.S., in 1910; in 1912 appeared his dissertation for the doctorate at Yale and in 1914 his Memoir "Arisaig-Antigonish District."

The excellent tables accompanying this memoir indicate the advances made, from the time of Honeyman's first survey in 1864, by Dawson (1868-1891), Fletcher (1886), Ami (1901), and Twenhofel (1901).

Williams introduces a few new formational names, and employs the terms Pennsylvanian and Mississippian. The body of the report is admirable in emphasizing type fossils and shows the influence of Professor Schuchert of Yale in the attention paid to the conditions of sedimentation. The more general of Williams' tables is given below (in part) to indicate our present view of the Palaeozoic sequence in this district.

WILLIAMS' TABLE OF PALAEOZOIC STRATA IN NOVA SCOTIA

Era	Period	Formation	Correlation
Quaternary	Recent Pleistocene		
Palaeozoic	Pennsylvanian(?) (Upper Carboniferous)	Listmore	Millstone Grit (?)
	Mississippian (Lower Carboniferous)	Ardness	Part of Windsor Series
		McArras Brook	
	Lower Devonian	Knoydart	Lower Old Red Sandstone
	Silurian	Arisaig Series Stonehouse	Ludlow (in part)
		Moydart	Louisville (U.S.) Wenlock (Eng.)
		McAdam	Rochester (U.S.) Up. Llandovery (Eng.)
		Ross Brook	Clinton (U.S.) Low. Llandovery (Eng.)
		Beechhill Cove	Low. Llandovery (Eng.)
	Ordovician(?)	Malignant Cove	
	L. Ordovician	Browns Mountain Group Baxters Brook	
		James River	

Other names must be mentioned as illustrating the group of which Dr. Williams was the pioneer: among these are Drs. W. J. Wright, A. O. Hayes, and W. A. Bell. These gentlemen have added much to the detailed stratigraphy of the Carboniferous. The outstanding feature of their work is the introduction of American terms and the attempt to correlate the maritime Carboniferous strata with those of the American interior sea. The following classification of the Horton-Windsor series published in 1921 is illuminating:—

TABLE OF NOVA SCOTIA STRATA

Tennesseean (Chesterian)
  Windsor series (marine)
Tennesseean (Meramecian)
  Cheverie series (terrestrial)
Waverlian (Kinderhookian)
  Horton series (terrestrial)
Silurian and Pre-Cambrian slates and Devonian.

Dr. G. F. Matthew in a paper read before this society in 1908 gave the following generalized classification of the Cambrian or Cambro-Ordovician cycle of sedimentation: it is extremely significant of his style and method:—

MATTHEW'S TABLE OF CAMBRIAN STRATA

St. John
  Division 3
 Band e—Leptobolus
 Band d—Tetragraptus
 Band c—Dictyonema
 Band b—Peltura
 Band a—Parabolina

  Division 2
 Band c—Olenus
 Bands a and b—Paradoxides

  Division 1
 Band c—Paradoxides
 Band b—Protolenus

Etcheminian

Coldbrook

Matthew's system has prevailed with little modification. He was himself doubtful as to the Cambrian or Ordovician age of Division 3 of the St. John Group and the position of the Coldbrook. A. O. Hayes in the Summary Report of the Geological Survey for 1913 gives an interesting table of the stratigraphy of the St. John region, which is reproduced in part below:—

HAYES' TABLE OF NEW BRUNSWICK STRATA

15	Recent	
14	Pleistocene	
13	Carboniferous	Red Head Mispeck Bloomsbury and Little River
12	....	
11	....	
10	Cambro-Ordovician	St. John Group, Div. C3
	Cambrian	St. John Group, Div. C2 St. John Group, Div. C1 Etcheminian
9	Cambrian? May be Pre-Cambrian	Coldbrook
8	Called Pre-Silurian by Bailey. May be Pre-Cambrian	Kingston
7	Pre-Cambrian	Portland
6	Age uncertain. Older than 13	Portland

This table indicates that the complicated geology of the Lower Palaeozoic and Pre-Cambrian of the maritime provinces is not yet entirely solved. Matthew's work is pre-eminent here and one can not close this section without a final tribute to his long labours—his indefatigable field work, his application of phylogenetic methods, his palaeobotany of the Carboniferous, Devonian, and Silurian, his work on amphibian footprints, and above all his rigid and consistent refusal to divorce palaeontology from stratigraphic geology.

In closing, also, mention must be made of the excellent contribution to palaeobotany by Miss Marie C. Stopes, "The 'Fern Ledges' Carboniferous Flora of St. John, New Brunswick," being Memoir No. 41 of the Geological Survey of Canada.

Province of Quebec

Advances in stratigraphic geology in Quebec during the past twenty years are difficult to review, being many and varied but for the most part local. It would be tedious to consider them here; we must in consequence limit our remarks to a few of the outstanding achievements.

The famous section at Levis was examined in detail by Raymond in 1911, 1912, and 1913; he divides it into 25 stratigraphic units in which he recognizes four distinct faunal zones. The famous Anticosti Island section, first reported on by Richardson 1853-1856, and by Billings in 1886, was studied in great detail by Charles Schuchert and W. H. Twenhofel. Both authors contributed a paper to the Geological Society of America in 1910 containing an account of the stratigraphy. Twenhofel supplemented this by a faunal description published as Museum Bulletin No. 3 of the Geological Survey in 1914. The subdivisions of Richardson and Billings are recognized, but new formational names are adopted and very extended lists of fossils given. The work is of continental importance in that the Gamachian series, not elsewhere known in America, is recognized as the summit of the Ordovician formations. The table of classification is given below:—

TWENHOFEL'S TABLE OF ANTICOSTI STRATA

- Silurian
  - Anticosti series
    - Chicotte
    - Jupiter River
    - Gun River
    - Becsie River
- Ordovician
  - Gamachian series
    - Ellis Bay formation
  - Richmond series
    - Charleton formation
    - English Head formation
  - Utica (?)
    - Macastey black shale

Gaspé, made famous geologically by the early efforts of Sir Wm. Logan, and the Magdalen islands have furnished Dr. J. M. Clarke, Director of the New York State Museum, with material for several important publications: "Sketches in Gaspé," "Observations on the Magdalen Islands," Geological Map of Percé," "Percé, a brief History of its Geology," and "Microscopic Fauna of the Bonaventure Formation." The geology of Gaspé likewise occupies a very prominent place in Clarke's monumental work, "Early Devonic History of

New York and Eastern North America," being Memoir 9, 1908-1909, of the New York State Museum.

This work is of great importance for its accurate determination of the Devonian faunas, for its incorporation of suggestions by Ells and Ami as to the age of certain of Sir Wm. Logan's original subdivisions, and for the practical endorsation of the stratigraphy of that pioneer investigator.

CLARKE'S TABLE OF GASPÉ STRATA

The Devonian section of Gaspé is given as follows:—
Gaspé sandstones
Grand Grêve limestones (Logan's Nos. 7 and 8)
Cap Bon Ami beds (Logan's Nos. 3, 4, 5, 6)
St. Albans beds (Logan's Nos. 1 and 2)

This work also contains an interesting review of the Devonian of St. Helen's island, of Scaumenac Bay, and of the outlier at Dalhousie, N.B.

The last reference to the geology of Quebec that space will permit is to the work of Dr. A. J. Foerste who prepared for the Geological Survey a report on "Upper Ordovician Formations in Ontario and Quebec," which was published in 1916 as Memoir 83. Dr. Foerste brought to this work an intimate knowledge of the Ordovician of the Ohio region; it is not remarkable, therefore, that the outstanding feature of his report is the correlation of Canadian formations with those of the United States. The work shows the modern tendency in the detailed sections, each with its fauna separately indicated. Dr. Foerste's classification is given below; it will be observed that many names of American formations are for the first time introduced into Canadian geology.

FOERSTE'S CLASSIFICATION OF THE ORDOVICIAN

- Silurian
  - Medina
- Ordovician
  - Richmond
    - Whitewater
      - Queenston
      - Saluda
    - Waynesville
    - Horizon undefined

FOERSTE'S CLASSIFICATION OF THE ORDOVICIAN—*Cont'd*

Lorraine
- Maysville
- Eden
- Horizon undefined

Utica
Collingwood
Trenton

Older Ontario

The chief contribution to the stratigraphic geology of lower Ontario in the early part of our period was the "Hamilton Group of Thedford, Ontario," published in the Bulletins of the Geological Society of America by Shimer and Grabau in 1902. The authors divide the formation into five faunal zones, give complete lists of fossils, some new, also interesting discussions of the phylogeny of type forms and correlation with American deposits.

Grabau and Scherzer in a study of the Monroe formation, published by the Michigan survey in 1909, did much to clear up the complicated problem of the Silurian-Devonian contact in Essex county. Their conclusions, which have not gone unchallenged, were as follows:—

GRABAU AND SCHERZER'S DIVISIONS OF THE MONROE FORMATION

Dundee (Onondaga)		
Monroe formation Monroean	Upper Monroe or Detroit River series	Lucas dolomite Amherstberg dolomite Anderdon limestone Flat Rock dolomite
	Sylvania sandstone and dolomite	
	Lower Monroe or Bass Island series	Raisin River dolomite Put-in-Bay dolomite Tymochtee shales Greenfield dolomite
Salina formation		

Important contributions to this question were also made by Rev. Thomas Nattress in 1910 and 1911.

The first sign of revival on the part of the Canadian authorities was the appointment of Dr. C. R. Stauffer, then Professor of Palaeontology at Queen's University, to prepare a report on the Devonian of Southwestern Ontario. The results of his investigations appear in Memoir 35, 1915, of the Geological Survey. Complete lists of fossils from all the more important exposures are given and a revision of the stratigraphy as follows:—

STAUFFER'S CLASSIFICATION OF THE DEVONIAN OF ONTARIO

Upper Devonian	Port Lambton beds (probably Portage and Chemung) Huron shale (probably Genesee shale)	
Middle Devonian	Hamilton formation	Ipperwash limestone Petrolia shale Widder beds Olentangy shale
	Delaware limestone	
	Onondaga limestone	Onondaga limestone Springvale sandstone (local facies)
Lower Devonian	Oriskany sandstone Helderbergian (wanting or possibly represented, in part, by the Detroit River series)	

The Silurian of the southwestern peninsula was studied by M. Y. Williams and an exhaustive report published as Memoir 111, in 1919. The report contains many faunal lists, and descriptions of a few new forms. Of chief importance is the recognition of many of the American subdivisions and a good correlation table. The Sylvania sandstone and Upper Monroe of Grabau and Scherzer are removed to the Devonian. The section on the Niagara river which is indicative of the general advance in stratigraphy since 1863, is given below:—

WILLIAMS' CLASSIFICATION OF THE SILURIAN OF ONTARIO

Devonian	
Silurian	
Cayugan Group	
Akron	Akron dolomite
Bertie	Bertie waterlime
Salina	Camillus shale
Guelph	Guelph dolomite

WILLIAMS' CLASSIFICATION OF THE SILURIAN OF ONTARIO—*Cont'd*

Niagara Group		
	Lockport	
		Eramosa beds
		Dolomite
		Gasport
	Rochester	Rochester shale
	Clinton	Irondequoit dolomite
		Williamson (?) shale
		Reynales (Wolcott) dolomite
		Furnaceville (?) (Sodus) shale
	Medina-Cataract	
		Thorold sandstone
		Grimsby sandstone
		Cabot Head shale
		Manitoulin beds
		Whirlpool sandstone

Raymond, in 1912, subdivided the Trenton of Ontario as follows:

4. Hormotoma zone
3. Prasopora zone
2. Crinoid zone
1. Dalmanella zone

He is also responsible for dividing the strata previously known as "Utica" into a lower series, the "Collingwood" and an upper "Utica."

In addition to these more important individual works we have evidence of a revived interest in stratigraphy in Foerste's "Upper Ordovician of Ontario and Quebec," Williams' "Ordovician of Lake Temiskaming" and the dissertation for the doctorate at Yale by G. S. Hume, entitled "The Stratigraphy and Geologic Relations of the Palaeozoic Outlier of Lake Temiskaming," 1920.

Palaeozoic of Hudson Bay

The early expeditions of Bell, McInnes, Dowling, Tyrrell, and others and the descriptions of fossils by Whiteaves, prior to the beginning of the present century, had laid the foundation of our knowledge of this region. We must pass over numerous small additions and refer only to the present status of the stratigraphy. It may be briefly stated that during quite recent years we see the same tendencies at work which have been conspicuous in southwestern Ontario

—the formational subdivision of the strata and correlation with the better known American members.

The first of these more recent additions was a description of Devonian fossils by the present writer published by the Ontario Bureau of Mines in 1904. After a considerable interval appeared Miller's "District of Patricia" in 1912—a comprehensive synopsis of the information available for the region. In 1913 J. B. Tyrrell published in the Reports of the Bureau of Mines of Ontario an account of the geology of Patricia: this was accompanied by a report by the present writer on the Palaeozoic fossils, which was afterwards reproduced in greater detail by the Royal Canadian Institute.

In 1919 M. Y. Williams reported on the Matagami and Abitibi rivers and published the first attempt to correlate closely the strata as follows:—

WILLIAMS' TABLE OF THE PALAEOZOIC OF HUDSON BAY

Devonian	Portage
	Genesee (?)
	Tully
	Hamilton
	Onondaga
Silurian	Salina
	Queenston
Ordovician	Basal Clastics

In 1920 the same author reporting on a region farther north recognized Onondaga, Salina, Guelph, and Niagara strata.

A more comprehensive account and one indicating fully our present knowledge of the stratigraphy appeared in the Bulletins of the Geographical Society of America, 1919, by the joint authors, T. E. Savage and Francis M. Van Tuyl. This publication contains full faunal lists and the following stratigraphic classification, which is much in advance of any hitherto published:—

SAVAGE AND VAN TUYL'S TABLE OF THE PALAEOZOIC OF HUDSON BAY

Upper Devonian
- Long Rapids shale
- Abitibi River limestone

Middle Devonian
- Sextant sandstones and shales

SAVAGE AND VAN TUYL'S TABLE OF THE PALAEOZOIC OF HUDSON BAY—*Cont'd*

Silurian
Niagaran
Attawapiskat coral reef
Ekwan River limestone
Alexandrian
Severn River limestone
Port Nelson limestone
Ordovician
Cincinnatian
Shammattawa limestone
Mohawkian
Nelson River limestone

Finally we must record the finding of Cretaceous clays on the Matagami river by Mr. Joseph Keele, an interesting account of which important discovery was given before this Section at the last annual meeting.

The Great Plains

Little has been added to the excellent work of Tyrrell and Dowling on the Palaeozoic of the Manitoba Lakes region. In 1912 E. M. Kindle reviewed the geology, gave faunal lists, and separated the lowest Devonian as a basal division with the name "Elm Point Limestone." In the far north the palaeozoics have received more consideration on account of the recent developments in search of oil. A more detailed classification and a wealth of fossil evidence are being prepared for publication at the present time.

A. E. Cameron in 1916 and 1917 gave the following classification of the rocks of the Great Slave Lake district:—

CAMERON'S CORRELATION OF THE STRATA OF GREAT SLAVE LAKE

Upper Devonian	
Hay River limestone	Chemung
Hay River shales	Chemung
Simpson shales	Portage
Middle Devonian	
Slave Point limestone	Manitoban
Presqu'ile dolomite	Winnipegosan
Pine Point limestone	Elm Point limestone
Upper Silurian	
Fitzgerald dolomite	
Red Rock arenaceous limestone	

In 1921 Kindle and Bosworth correlated the rocks of the Lower Mackenzie with those of Great Slave Lake and the Upper Mackenzie as follows:—

KINDLE AND BOSWORTH'S TABLE OF MACKENZIE RIVER STRATA

	Lower Mackenzie	Upper Mackenzie and Great Slave Lake
Upper Devonian	Bosworth sandstone and shale Fort Creek shales	Hay River limestone and shale Simpson shales
Middle Devonian	Beavertail limestone Ramparts limestones Hare Indian River shales	Slave Point limestone Presqu'ile dolomite Pine Point limestone
Silurian	Bear Mountain formation Lone Mountain dolomite	Fitzgerald dolomite

Mesozoic and Tertiary stratigraphy in the region of the great plains owes much to the long continued labour of Dr. Dowling and his assistants. Dowling's "Southern Plains of Alberta," 1917, sums up our knowledge practically to date. No better appreciation of the advances in stratigraphy can be gained than by comparing the table following with that on page 11.

DOWLING'S CLASSIFICATION OF THE MESOZOIC STRATA OF THE GREAT PLAINS

	Western Montana	Bow and Belly Region (Dawson 1882-84)	Southern Alberta	Central Montana	Manitoba	South Dakota
Montana group	Bearpaw shale (marine)	Pierre-Foxhill (marine)	Bearpaw shale, 622 feet (marine)	Bearpaw shale (marine)		
	Two-Medicine formation (Fresh water and brackish water)	Belly River series (fresh water and brackish water)	Pale beds, 651 feet (mostly fresh water)	Judith River formation (mainly fresh water)	Odanah and Millwood shales (marine)	Pierre shales (marine)
			Foremost beds 200 to 300 feet (brackish water)			
			Pakowki shales, 300 feet, thicken eastward (marine)	Claggett shales (marine)		
	Virgelle sandstone		Milk River sandstone, 316 feet in west 200 at Taber (fresh water and brackish water)	Eagle sandstone (marine at top and bottom)		
Colorado group	Benton shales (marine)	Lower dark shales of Rocky Spring ridge (marine)	Benton, exposed in northern Montana, 1,776 feet in Sweet Grass hills (marine)	Niobrara-Benton shales (marine)	Niobrara shales Benton shales	Niobrara shales Benton shales
Dakota group			Shales and sands exposed in Sweet Grass hills.		Dakota sandstone	Dakota sandstone

Several important contributions were made by Wm. McInnes notably on the Pasquia hills and on the Saskatchewan River district, and Professor Alex. MacLean contributed several papers dealing with the detailed stratigraphy of southern Manitoba and Saskatchewan. Investigations were carried into the far north by F. H. McLearn, E. M. Kindle, and T. O. Bosworth.

An interesting table indicative of the type of work being done in these northern regions is that given by McLearn in the Summary Report of the Geological Survey for 1920.

McLEARN'S TABLE OF NORTHERN STRATA

Mesozoic
- Cretaceous
  - Bullhead Mountain formation
    - Upper member
    - Lower member
- Triassic
- (Upper)
  - Schooler Creek formation
    - Zone of *Pseudomonotis*
    - Zone of *Halobia*
    - Zone of *Spiriferina-Terebratula*

No account of the great plains is complete without mention of Dowling's paper read before this society in 1915, entitled "The Cretaceous Sea in Alberta." Valuable in itself for the actual information conveyed it is still more significant as portraying the modern method of treating geological problems, *i.e.*, the consideration of strata as the record of sea movements rather than as mere structural elements.

The Cordillera

We have seen that in 1900 a substantial skeleton, but only a skeleton, had been established for the maze of formations of British Columbia. Since that time the workers have been many and the progress remarkable. Disregarding the extraordinary amount of publication due to the investigation of mining areas, it may perhaps be said that in stratigraphic advance alone British Columbia holds the first place for the past twenty years.

The numerous reports on coal fields alone contain a mass of stratigraphic detail, and, unfortunately, a multiplicity of local formational names. By way of example may be mentioned the following:—

Leach, W. W. —Crows Nest Coal Fields, 1901.
Leach, W. W.—Blairmore-Frank Coal Fields, 1902.
Dowling, D. B.—The Coal Basins in the Rocky Mountains, etc., 1903.
Ells, R. W.—Nicola Coal Basin, 1904.
Dowling, D. B.—The Cascade and Costigan Coal Basins, etc., 1904.
Dowling, D. B.—The Northern Extension of the Elk River Coal Basin, 1905.
Poole, H. A.—The Nanaimo-Comox Coal Field, 1905.
Dowling, D. B.—Rocky Mountain Coal Areas, between the Bow and Yellowhead Passes, 1906.
Malloch, G. A.—The Cascades, Palliser, and Costigan Coal Basins, 1907.
Dowling, D. B.—Report on the Cascade Coal Basin, 1907.
Cairnes, D. D.—Moose Mountain District of Southern Alberta, 1907.
Malloch, G. A.—The Bighorn Coal Basin, 1908.
Dowling, D. B.—Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern B.C., 1909.
Dowling, D. B.—Coal Fields of Jasper Park, Alberta, 1910.
Malloch, G. S.—Bighorn Coal Basin, Alberta, 1911.
Malloch, G.A.—Reconnaissance on the Upper Skeena River, etc., 1911.
Clapp, Charles M.—Comox and Suquash, Vancouver Island, 1911.
Malloch, G. A.—The Groundhog Coal Field, 1912.
MacKenzie, J. D.—South Fork Coal Area, 1912.
Dowling, D. B.—Coal Areas in Flathead Valley, B.C., 1913.
Dowling, D. B.—Coal Fields of British Columbia, 1915.
MacKenzie, J. D.—Geology of a Portion of the Flathead Coal Areas, 1916.
MacVicar, J.—Foothill Coal Areas North of the G.T.P.R., 1916.
Rose, B.—Crowsnest Coal Field, Alberta, 1916.
Rose, B.—Crowsnest and Flathead Coal Areas, 1917.
Rose, B.—Northern Part of Crowsnest Coal Field, 1918.
Rose, B.—Highwood Coal Area, Alberta, 1919.
Dowling, D. B.—Coal Fields South of the Grand Trunk Pacific Railway in the Foothills of the Rocky Mountains, Alberta, 1919.
Marshall, J. R.—Upper Elk River Valley, 1920.

It is hopeless to review this bulk of information. The table alone will serve our present purpose of impressing the extraordinary advances made in the stratigraphy of the coal areas.

Concerning the coast and islands we find first Dr. Ells' Report on Graham Island which appeared in 1904. The stratigraphic column is here divided only into Post-Tertiary, Cretaceous, and Igneous Rocks comprising Pre-Cretaceous and later Tertiary. Next comes the LeRoy report on the more southerly coast and islands in 1908, containing a table which indicates only slight advances on previous determinations. This table is given below:—

LEROY'S CLASSIFICATION OF THE STRATA OF THE COAST AND ISLANDS OF BRITISH COLUMBIA

Palaeozoic	Devono-Carboniferous	Texada group. Made up largely of igneous rocks with some limestones and slates. Britannia group. Conglomerates, quartzites, slates, sericite schists. Marble Bay formation. Limestones.
Mesozoic	Triassic (?)	Basic eruptives.
	Jurassic Upper (?)	Coast Range batholith.
	Cretaceous	Conglomerate, sandstones, shales.
Tertiary	Eocene	Puget group. Conglomerates, sandstones, shales, with little impure lignite.
	Post-Eocene	Trachytes and andesites in flows and dikes.
Quaternary	Pleistocene	Boulder clays with some modified drift.
	Modern	Stratified gravels, sands, and clays.

The great advances in stratigraphic subdivision accomplished between that time and the present may be seen by comparing with the above the excellent table for Queen Charlotte island given by J. D. MacKenzie in 1916 and that given by Clapp for the Nanaimo Map Area in 1914.

MacKenzie's table is too extended for reproduction here; it gives not only the sequence in Queen Charlotte island but correlations with eight other localities in British Columbia, Alaska, or Alberta. The skeleton of the table is as follows:—

Cenozoic	
Quaternary	
Pliocene	Masset formation
Miocene	Skonum formation
Eocene	Etheline formation
Mesozoic	
Upper Cretaceous	Queen Charlotte series
Lower Cretaceous	
Upper Jurassic	Batholithic intrusives
Middle Jurassic	Yakoun formation
Lower Jurassic	Maude formation

Clapp's table of formations is very expressive of the great advances made in stratigraphic subdivision since the time of LeRoy's report.

CLAPP'S CLASSIFICATION OF THE ROCKS OF VANCOUVER ISLAND

Quaternary	Recent	Post-Glacial	Beach alluvium. Swamp, valley, and delta alluvium. Rock debris.
	Pleistocene	Later Glacial epoch	
		Stage of glacial retreat	Colwood sands and gravels.
		Stage of glacial occupation	Vashon drift.
		Interglacial epoch	Puyallup clays, sands, and gravels.
		Earlier Glacial epoch	Admiralty till.
Tertiary	Eocene (?)		Dacite porphyrite dykes.

CLAPP'S CLASSIFICATION OF THE ROCKS OF VANCOUVER ISLAND—*Cont'd*

Mesozoic	Upper Cretaceous	Nanaimo series. Gabriola formation	Chiefly sandstones.
		Northumberland formation.	Conglomerates, sandstones, and shales.
		DeCourcy formation.	Chiefly sandstones.
		Cedar District formation	Chiefly shale
		Protection formation (Douglas coal seam)	Grits, sandy shales; contains Douglas coal seam
		Newcastle coal seam	
		Cranberry formation	Shaly sandstones and sandy shale; some coarse sandstones and conglomerates
		Extension formation	Chiefly conglomerates, some shales, sandstones, and small coal seams
		Wellington coal seam	
		East Wellington formation	Chiefly sandstone
		Haslam formation (Marine shales)	Chiefly shale; some calcarinites
		Benson formation	Basal conglomerates

CLAPP'S CLASSIFICATION OF THE ROCKS OF VANCOUVER ISLAND—*Cont'd*

Mesozoic	Upper Jurassic and possibly, Lower Cretaceous	Granitic intrusives	
		Sicker gabbro porphyrite (Position in column doubtful)	Masses and dykes
		Saanich granodiorite	Batholith
		Gabbro-diorite	Peripheral facies of Saanich granodiorite
	Lower Jurassic and Triassic	Vancouver group	
		Sicker series (Position in column doubtful)	Slaty and quartzose metamorphic sediments
		Vancouver volcanics	Meta-andesites and meta-basalts

The Palaeozoic section of the Rocky mountains proper was established in outline chiefly by Dawson and McConnell as we have already seen. The past twenty years have seen many advances due to the labours of D. B. Dowling, J. A. Allan, S. E. Slipper, H. W. Shimer, S. J. Schofield, L. D. Burling, R. W. Brock, R. A. Daly, and others working under the authority of the Geological Survey of Canada. In addition, we have to record with the greatest appreciation the epoch-making advances in Cambrian stratigraphy and palaeontology made by Dr. C. D. Walcott of the Smithsonian Institution.

For the gradual acquisition of stratigraphic facts too much credit can not be given to the various workers in the coal fields through whose labours the detail was gradually worked out. The report of H. W. Shimer in 1910 contains a table of the Palaeozoics of the Lake Minnewanka section not differing greatly from that of Dowling:—

SHIMER'S TABLE OF PALAEOZOIC STRATA OF THE ROCKIES

Permian	Upper Banff shale
Pennsylvanian	Rocky Mountain quartzite Upper Banff limestone Lower Banff shale
Mississippian	Lower Banff limestone
Devonian	Intermediate limestone
Cambrian	Castle Mountain group

In Guide Book No. 8 of the International Geological Congress, J. A. Allan gives an extended table of the generalized Palaeozoic section: it corresponds with the above with the addition of a formation—the Sawback—provisionally ascribed to the Devonian below the Intermediate limestone, the Silurian Halysites beds, and the Ordovician divisions—Graptolite shales and Goodsir shales. The Cambrian sequence given below indicates the great advances since the time of G. M. Dawson:—

ALLAN'S TABLE OF THE CAMBRIAN OF THE ROCKIES

Upper Cambrian	Lower Cambrian
Ottertail limestone	Mount Whyte
Chancellor	St. Piran
Sherbrooke	Lake Louise
Paget	Fairview
Bosworth	
Middle Cambrian	
Eldon	
Stephen	
Cathedral	

The Palaeozoic section in the Mount Robson district is given by Walcott as follows:—

WALCOTT'S CLASSIFICATION OF THE CAMBRIAN

Ordovician	Lower Cambrian
Robson limestones	Hota formation
Upper Cambrian	Makto limestone
Lynx limestones	Tah formation
Middle Cambrian	McNaughton sandstones
Titkana limestones	
Mumm limestones	
Hitka formation	
Tatay limestones	
Chetang limestones	

Schofield's report on the Cranbrook Map area which appeared in 1915 is indicative of work somewhat farther west; and is an excellent example of a just combination of stratigraphic and economic geology. The Palaeozoic strata are classified as follows:—

SCHOFIELD'S TABLE OF THE PALAEOZOIC OF CRANBROOK

Mississippian	Wardner formation
Devonian	Jefferson formation
Middle or Upper Cambrian	Elko formation
Middle Cambrian	Burton formation

A comparison of these tables shows that there is room for further correlation. The Permian age of the Upper Banff shale and the Mississippian age of the Lower Banff limestone is questioned. Burling differs from Walcott in certain views regarding the Cambrian sequence, but while much remains to be done it is apparent that the stratigraphy of the Palaeozoic of the mountains has received much attention and wonderful advances have been made during the first two decades of this century.

The Palaeozoic stratigraphy of the western geosyncline can be but briefly mentioned. We have seen that Dawson recognized the Carboniferous age of the Cache Creek series and thus laid the foundation for future development, with which is connected the names of Charles Camsell, N. L. Bowen, S. J. Schofield, and L. D. Burling.

The Mesozoic and Tertiary formations have likewise been examined in detail, particularly the former on account of the association with coal. It is almost unnecessary to state that again we are deeply indebted to the workers in the coal fields. Since 1900 the Cretaceous has been subdivided and strata of Jurassic and Triassic age recognized. In the Rockies and foothills of the southern section we have now the following sequence of the Mesozoic:—

MESOZOIC FORMATIONS OF THE ROCKIES AND FOOTHILLS

Cretaceous
Upper Ribboned sandstone
Kootenay coal measures
Lower Ribboned sandstone
Jurassic
Fernie shale

Indicative of investigations farther afield may be cited the report of F. H. McLearn, 1921, on the Upper Peace River, already referred to in speaking of the Cretaceous of the plains. Time will not permit a review of the work farther west: it must suffice to state that this region likewise has not been neglected and we have to record notable advances in the Mesozoic stratigraphy both in the south and along the line of the National Transcontinental railway.

Palaeontology 1900 to Present

We must now review briefly the development of pure palaeontology during the two decades we are considering. Dr. J. F. Whiteaves died on the 8th of August, 1909, and palaeontology suffered thereby an irreparable loss. He was succeeded by Dr. Percy E. Raymond as Invertebrate Palaeontologist to the Survey. Dr. Raymond's first report, contained in the Summary Report of the Survey for 1910, while short, is illuminative, for it indicates that Raymond is a field stratigrapher as well as a palaeontologist. The following quotation is typical of Raymond's attitude to palaeontology:

"Several days were spent in studying the stratigraphy and collecting the fossils of the Chazy formation at Aylmer, Ottawa, Grenville, Quebec Junction, Bordeaux, and Pointe Claire. These latter studies are still incomplete, but enough facts have been obtained to show that the lower 125 feet of the Chazy formation in the Ottawa valley, as defined in the Geology of Canada, 1863, is of Upper Chazy age, while the black and buff limestones above belong to the Black River group."

Raymond contributed several purely palaeontological papers dealing more particularly with the detailed anatomy of trilobites and rare forms of echinoderms. In stratigraphic work he subdivided the Beekmantown into Theresa and Beauharnois; established the upper age of the Chazy of Ontario and Quebec, calling it the "Aylmer" formation, and subdivided the Black River into Pamelia, Lowville and Black River. His work on the Trenton has already been mentioned. An elaboration of his classification with new formational names and descriptions of fossils appeared as Museum Bulletin 31 in 1921. This paper marking a distinct advance in the stratigraphy of the Trenton, discards "Utica" as a formational division but retains the Collingwood, previously established by Raymond, as a subdivision of the Trenton group. This table is so important that it is reproduced on page 43 but without the correlation given in the original.

RAYMOND'S SUBDIVISIONS OF THE TRENTON GROUP

	Zonal name
Collingwood	Asaphus canadensis zone
Upper Cobourg	Hormotoma zone or Sponge beds
Lower Cobourg	Rafinesquina deltoidea zone
Trenton (restricted)	Cystid beds; Prasopora zone
Hull	Crinoid beds
Rockland (Triplecia beds)	Dalmanella zone

Dr. Raymond retired from the Survey in 1912 and was followed by Dr. E. M. Kindle as Invertebrate Palaeontologist. Kindle, like Raymond, is not purely a laboratory palaeontologist but has devoted much time to field work and stratigraphic problems and has contributed important investigations on the peculiarities of stratified rocks and their manner of formation. He is responsible for the discovery of a Portage fauna in the basin of the Mackenzie River and for the addition of the Elm Point formation to the Devonian of Manitoba. Mr. E. J. Whittaker and Miss Alice Wilson of Dr. Kindle's staff have also contributed valuable additions to palaeontological literature.

Canadian palaeontology has been advanced greatly during the past twenty years by many of the authors whose work has been referred to in reviewing the stratigraphic development. It will be remembered that a more extended knowledge of fossils was emphasized as a characteristic of the new school of stratigraphers. In many cases new species have been described by the authors and even special papers on palaeontological subjects issued, as illustrated by the several contributions of Dr. F. H. McLearn. In this connection we must again refer to the great volume of purely palaeontological achievement due to the labours of Dr. John M. Clarke in the east and of Dr. C. D. Walcott on the Cambrian of the Rocky mountains. Reference must also be made to reports on special palaeontological problems published by authors not members of the staff of the Geological Survey:

George H. Girty—Carboniferous Fossils from Yukon-Alaskan Boundary.
Carboniferous Fossils from the Upper White River.

Dr. Ray S. Bassler—Bryozoan Fauna of the Rochester shale.
Dendroid Graptolites of the Niagara dolomites at Hamilton, Ont.

D. P. Penhallow—North American Species of Dadoxylon.
Pleistocene Flora of Canada.
Cretaceous and Tertiary Plants.

Concerning the progress of Invertebrate Palaeontology in the universities it may be said that the achievement is not great. The writer may be permitted to enlarge, perhaps unduly, on what has been accomplished at Toronto, with which alone he is familiar. The donation of fossils and books made by Sir Edmund Walker about 1900 formed the nuclei of museum and library which have grown during the past twenty years to considerable dimensions. The collections now constitute the Royal Ontario Museum of Palaeontology and the library is also separately organized as the Library of Palaeontology of the University of Toronto. Materially, therefore, considerable progress has to be recorded. Academically the subject of palaeontology has received a degree of recognition far in excess of that which it enjoyed in earlier days. The undergraduate courses have been strengthened and a beginning has been made in post-graduate work. The actual contributions to science consist of a number of papers by the writer and more recently by Miss Helen Stewart and Mr. W. S. Dyer.

Prior to 1911 stratigraphic geology and palaeontology at Queen's University were merged with other branches of the science, but in that year Dr. C. R. Stauffer was appointed to teach palaeontology; he remained but a short time and was followed successively by Dr. J. Hyde, Dr. K. F. Mather, Dr. Bela Hubbard, Dr. F. J. Alcock, and Dr. Stanley Smith.

The work of Dr. Stauffer on the Devonian of Ontario is referred to elsewhere. In 1911 Dr. W. A. Bell published an account of the palaeontology of the Black River of Wolfe Island, and later Dr. Jesse Hyde contributed several articles on the Carboniferous of Nova Scotia to the Guide Books of the XIIth International Geological Congress. In 1916 Dr. Mather together with Dr. Kindle published a revision of the Ordovician in the vicinity of Kingston.

Recently Dr. M. Y. Williams has been placed in charge of palaeontology in the University of British Columbia and Mr. P. E. Warren in Alberta. In Manitoba the work is under the direction of Dr. E. Burwash.

At McGill University, Sir Wm. Dawson was succeeded by Dr. Frank D. Adams as Professor of Geology. Pre-Cambrian and economic geology as well as pure petrography owe much to the efforts of Dr. Adams; his work on the physical constants of rocks is of great value to any geologist whatever his field of endeavour may be. Had we included the Pre-Cambrian in our review, Dr. Adams' re-study of the Laurentian and his work, together with that of Dr. A. E. Barlow, in the Haliburton district, must have received particular mention. Dr. Adams and his associates, Dr. Bancroft, Dr. Coker, and Professor McKergow, have also devoted themselves to studies in experimental geology, but stratigraphy in the narrower sense and pure palaeontology have not received a due proportion of the efforts of the McGill staff.

Dr. Osborne resigned as Honorary Vertebrate Palaeontologist to the Survey in 1902 and Mr. Lawrence M. Lambe was appointed Vertebrate Palaeontologist. Between this time and his death in 1919 Lambe did much for the cause of vertebrate palaeontology in Canada. His numerous descriptions of new genera and species of dinosaurs and turtles from the Cretaceous of the west, his work on the fishes of the Albert shale, and on fish from the Palaeozoic of the Rockies; and his dissertations on certain mammalian teeth, etc., all attest his application to the subject and the volume of his productions.

Vertebrate palaeontology in Canada may also claim the work of Mr. Barnum Brown of the American Museum of Natural History, who collected in Alberta and published many important contributions to Canadian vertebrate palaeontology in the bulletins of his museum.

In 1918 the University of Toronto sent an expedition to collect vertebrate remains in the Cretaceous of Alberta and has followed this first attempt by an expedition in each subsequent year. The material results to date are three skeletons mounted and a large collection awaiting the work of the preparator. Scientifically a new species of a known genus and an entirely new genus have been described.

During the summer of 1921 the University of Alberta entered the field of vertebrate palaeontology in sending Mr. Geo. Sternberg to collect in the classic locality on the Red Deer river, Alberta.

Vertebrate palaeontology depends for its success as much on the work of the skilled preparator as on the efforts of the scientist. Great credit is due to Mr. C. H. Sternberg and his three sons, who have mounted practically all the Canadian material in our museums.

In conclusion, it is necessary to offer some apology for the length of this address: it is much too long for the purpose intended but it is all too short to do justice to the subject itself. The sins of omission must be pardoned in view of the complexity and local character of the development and the large number of names involved.

Canada has reason to be proud of the achievements of its Geological Survey not less in stratigraphy than in other branches of the science; but it is not wise to disguise the fact that most of the recent advances in stratigraphy and palaeontology are due to the efforts of workers from across the line or of men fresh from post-graduate courses in American universities. This should not be and the fault lies with our Canadian colleges. There is no intention to disparage the undergraduate work: it is admittedly as extensive as possible, but it must be remembered that a palaeontologist or stratigrapher can not be created by four years of undergraduate work. The remedy is obvious: post-graduate studies must be encouraged in our universities. To this end the co-operation of the Geological Survey of Canada and of the provincial bureaux is essential. The opportunities for geologists can never be very numerous; in consequence, the professors in our universities hesitate to assume the responsibility of actually advising students to make geology a life work. The greatest incentive given to the subject is the practice of employing undergraduate students on field parties: for this the universities owe the Survey a debt of gratitude. If the Survey or the Provincial bureaux could extend this privilege to the granting of independent commissions to a small number of graduate students, increase in this type of student would be at once apparent.

While it is true that this is now done, the uncertainty of appointment largely counteracts the advantage. The writer would appeal for some sort of arrangement whereby the universities could actually rely upon one or two appointments of this kind per annum. It is true that the Survey might in some instances suffer loss or disappointment, but on the whole, the general cause of education in geology would be immeasurably advanced.

Some Outliers of the Monteregian Hills

By W. V. HOWARD, B.A.

Presented by FRANK D. ADAMS, PH.D., D.SC., F.R.S., F.G.S., F.R.S.C.

(Read May Meeting, 1922)

INTRODUCTION

During the summer of 1921 the writer investigated a series of small basic intrusives which occur about twenty-five miles west of Montreal, and a detailed petrographic study of the rocks of which they are composed has shown that they are closely allied to, and form part of, the extensive series of alkaline rocks which have come to be known as the Monteregian Petrographical Province. The work was carried on under a grant from the Honorary Advisory Council for Scientific and Industrial Research.

It is the purpose of this thesis to describe the field occurrence of these western outliers, and by a detailed description of their petrographical and chemical composition to show their genetic relations with the already accepted Monteregians.

PREVIOUS WORK

The name Monteregian was given by Dr. F. D. Adams to a series of hills, eight in number, which extend across the Eastern Townships of the Province of Quebec, and which are members of a single Petrographical Province.[1] This province was originally considered by Logan to include Brome, Shefford, Yamaska, Rougemont, Beloeil, Mount Johnson, St. Bruno, Mount Royal and Rigaud Mountains.[2] O. E. Leroy showed, however, that Rigaud Mountain was not a Monteregian, but was rather an outlier of the Laurentians. Besides describing the main intrusions, Logan also noted the occurrence of a number of dykes, notably those at Chambly, Montreal, and Lachine, as well as a number of breccias at St. Helen's Island and Isle Ronde in the St. Lawrence River and at St. Anne de Bellevue and Isle Bizard.[3]

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[1]The Monteregian Hills, a Canadian Petrographical Province, by F. D. Adams; Journ. of Geol., Vol. XI, p. 239, 1903.

[2]Geology of Canada, 1863, pp. 655-669.

[3]Geology of Canada, 1863, pp. 355-358.

Dr. F. D. Adams described an alnoite dyke at Ste. Anne de Bellevue[1] and an alnoite-like dyke at St. Lin[2], twenty-five miles north of Montreal, both of which he considered Monteregian in character. In 1901 Miss Nolan and Miss Dixon[3] made a detailed examination of the breccia on St. Helen's Island, and in 1909 Dr. Robert Harvie re-examined the breccia localities mentioned by Logan, together with some new occurrences[4], and in 1921 Dr. N. L. Bowen of the Carnegie Geophysical Laboratory published a paper on the alnoitic intrusion at Isle Cadieux, twenty-seven miles west of Montreal.[5]

There is a tendency on the part of some American geologists to place some of the alkaline intrusives of the New England States in the Monteregian Petrographical Province, notably, Red Hill, Mt. Ascutney, and Mt. Monadnock. It does not lie within the province of this paper to discuss this relationship further.

General Statement

During the summer of 1921 the writer visited the occurrences at Isle Cadieux (described by Bowen) and La Trappe (described by Harvie) and also investigated some new localities, namely, Como, Ste. Monique, and Ste. Dorothée. The information obtained is incorporated in this paper, and the location of these outliers together with that of the other members of the province is shown on Figure 1.

The writer desires to acknowledge the valuable suggestions and assistance rendered in the preparation of this paper by Dr. H. S. Washington of the Carnegie Geophysical Laboratory, Dr. Robert Harvie of the Canadian Geological Survey, and Dr. F. D. Adams, Dr. J. J. O'Neill, Dr. H. C. Cooke, and Prof. R. P. D. Graham, all of McGill University, as well as the above-mentioned papers, and many others, and he has endeavoured in each case to give due acknowledgment.

The positions of the various members of the Monteregian Petrographical Province on the map accompanying this paper are taken from Guide Book No. 3, for the 13th International Geological Congress, issued by the Canadian Geological Survey in 1913, with the addition of the areas described on page 51 as well as several dykes including

[1]A. J. Sci. 3rd Series, Vol. XLIII, pp. 269-279, 1892.
[2]G.S.C. Ann. Rept., Vol. VIII, Pt. J, p. 136, 1895.
[3]Can. Rec. Sci. Vol. IV, No. 1, 1903.
[4]Trans. 4, Roy. Soc. of Can. 3rd Series, Vol. III, Sec. IV, pp. 252-299, 1909.
[5]A. J. Sci. 5th Series, Vol. III, pp. 1-34, Jan., 1922.

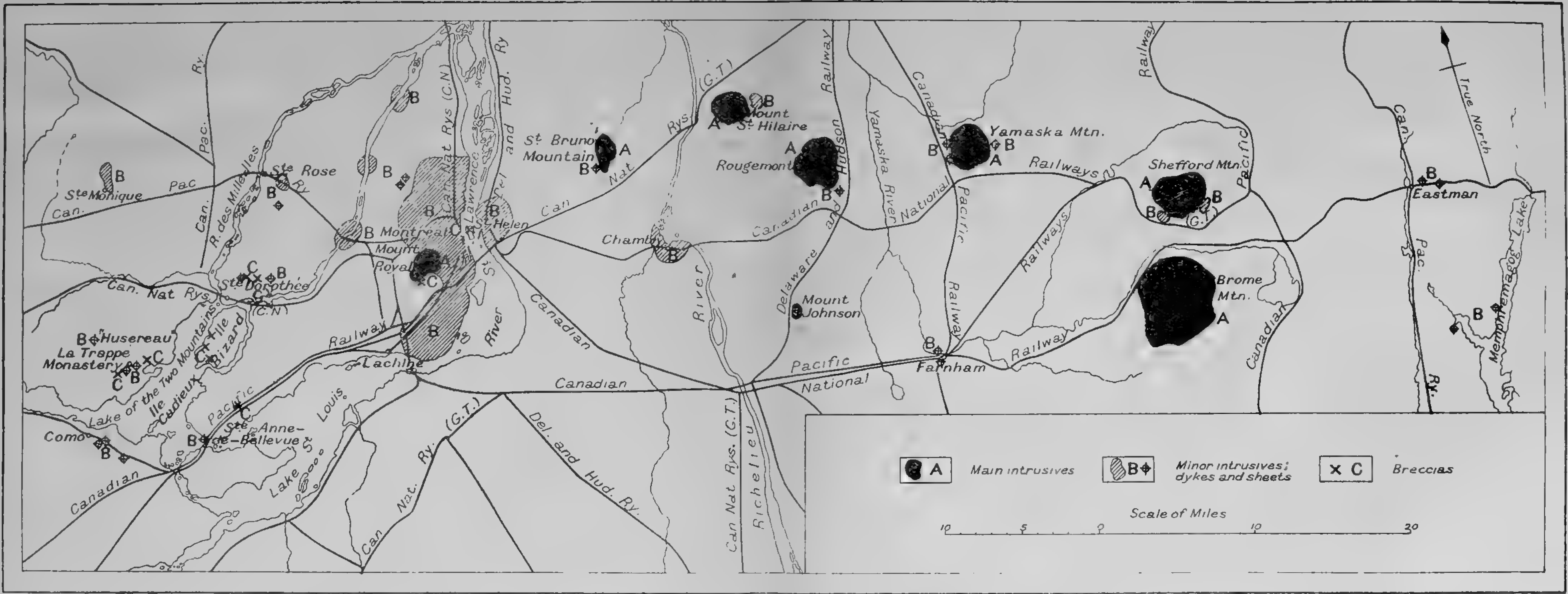

FIGURE 1.—THE MONTEREGIAN PETROGRAPHICAL PROVINCE

nordmarkite and camptonite in the eastern part of the area in the vicinity of Lake Memphremagog.

Location of the Monteregian Hills

In the St. Lawrence lowlands in the Province of Quebec, there stand out prominently eight isolated hills spaced at more or less equal intervals. These hills, known as the Monteregian Hills, extend almost due east and west for a distance of about fifty miles. They lie roughly in two parallel lines with a third cutting them at an angle of about 30°. The parallel lines lie approximately west north-west and east south-east, the northern series being composed of Shefford, Yamaska, Rougemont, and St. Bruno, and the other containing Brome, Mount Johnson, and Mount Royal. The intersecting line cuts these at St. Bruno and Mount Royal and extends eastward to St. Hilaire.

The cores of all these hills are composed of sodic igneous rocks and are either volcanic necks, or laccoliths; besides these larger masses, there are also small bosses, sheets, or systems of dykes or breccias either in line with the main bodies or forming subsidiary lines. Thus the Shefford-St. Bruno series can be extended eastward to include the exposure at Eastman,[1] and westward to include the dykes at Sault au Recollet, Ste. Rose, and the sheet at Ste. Monique. The Brome-Mount Royal series includes dykes at Chambly and Farnham and extends eastward through Bolton Centre to Lake Memphremagog where there are also associated dykes. West of Mount Royal, this line includes the sheet at Ste. Dorothée. The St. Hilaire-Mount Royal line spreads out to the west and includes all the breccias described by Harvie and the alnoites and associated rocks at Ste. Anne de Bellevue, Isle Cadieux, and La Trappe.

A similar grouping in lines running north and south is apparent. Ells[2] suggests that the intrusives lie on a parallel series of north-south faults. Thus lines joining Shefford and Brome, St. Hilaire, Johnson and the dykes around Lake Champlain, and the line joining the extreme western outliers are all parallel and lie in the direction suggested by Ells. There is, however, little direct evidence that hese lines represent lines of faulting, but it is quite probable that the intrusions took place along lines of weakness or deep-seated fracture.

[1]J. J. O'Neill, St. Hilaire and Rougemont Mountains, Quebec, Memoir 43 G.S.C., p. 8.

[2]R. W. Ells. Report on the South West Sheet. Eastern Townships Map, Ann. Rep. G.S.C. Vol. VII, Pt. J, p. 73.

Notes on the Physiography of the Region

The St. Lawrence lowlands occupy the area between the Laurentian highlands to the north and the Appalachian Mountains to the south and east. They extend from the Gulf of St. Lawrence to Lake Huron and are divided roughly into two parts by a spur of the Laurentians which extends across the St. Lawrence at the Thousand Islands to the Adirondack Mountains in New York State. East of this spur is a flat ridge which extends from the St. Lawrence River at Coteau, to the Ottawa River at Hudson, while on the north shore of the Ottawa is a group of hills known as the Oka Mountains or the Two Mountains. A flat plain covered by the sands and clays deposited by the Champlain Sea lies to the east of these elevations and extends eastward to the foot of the Appalachian Range. A study of the rocks underlying this plain shows that it is traversed by an extensive fault, known as the Champlain Fault, which passes through the Lake Champlain valley, and to the west of Yamaska, from which point it turns more to the north-east and passes down the valley of the St. Lawrence. West of this fault, the area is underlain by flat-lying or gently dipping sediments, while to the east the sedimentary rocks dip very steeply. The whole plain has been eroded uniformly to the present level regardless of structure and through the plain thus developed the Monteregian hills rise abruptly as a series of prominent hills. These intrusive bodies to-day form practically the only elevations above the plain, and we have a series of bold precipitous hills rising to heights of from 600 to 1,500 feet above the plain or from 700 to 1,500 feet above sea level, which give the impression of even greater height.

These hills are more precipitous on their northern slopes than to the south and usually the softer Palæozoic sediments extend for a considerable distance up the southern side as they were protected from the scouring action of the glaciers by the harder rocks immediately to the north. In the vicinity of Montreal and to the west of the city, small mounds and escarpments composed of igneous rocks allied to the Monteregians are of common occurrence. These owe their prominence above the plain to differential erosion. Usually these mounds mark the only outcrops visible in wide areas, excepting where streams have cut their way through the Quaternary sediments and drift, and have laid bare the Palæozoic rocks beneath.

General Geology

In the area with which this paper is concerned, the following succession is noted:

Quaternary	Champlain sands and clay Boulder clay
Palæozoic	Monteregian Intrusives Silurian and Devonian (present as fragments in breccias)
	Ordovician
	Utica shale Trenton limestone Black River formation Chazy limestone Beekmantown or Calciferous dolomitic limestone
	Cambrian
	Potsdam sandstone
Pre-Cambrian	Anorthosite Laurentian granites and gneisses Grenville Series, limestones and quartzites

Pre-Cambrian

Anorthosite.—Near Cartierville on the Island of Montreal is a small area underlain by anorthosite, identical with the Morin anorthosite.

Laurentian and Grenville Series.—The area to the north of the St. Lawrence lowlands is underlain by a complex series of Pre-Cambrian rocks including the Grenville Series of quartzites and crystalline limestones together with highly metamorphosed sediments in the form of schists and gneisses. The whole area was intruded by Laurentian granites and gneisses. In the Oka Mountains there is an outlier of Grenville limestones and quartzites intruded by Laurentian granites and gneisses.

Palæozoic

Cambrian. Potsdam Sandstone.—This formation which consists of a fine-grained, light-coloured, highly siliceous sandstone is found on the islands and west shore of Lake St. Louis, on the south-west shore of the Lake of Two Mountains as far as Rigaud, and also on the north shore of this lake flanking the Pre-Cambrian outlier of the Oka Mountains.

Ordovician. Beekmantown or Calciferous Formation.—This represents a transition stage between the Potsdam and the Chazy limestones, and is a granular magnesian limestone or dolomite.

It occurs on the shore of Lake St. Louis, the upper end of the Island of Montreal, the upper end of the islands of Isle Bizard and Isle Jesus, and continues past St. Eustache to St. Lin. This formation also occurs near St. Scholastique, where it divides into two parts, the northern extending to Lachute, and the southern to Rigaud Mountain.

Chazy Limestone.—The Chazy consists of a series of limestones associated with sandstones and shales. It crosses the Island of Montreal from Pointe Claire to Ste. Genevieve and underlies the central part of Isle Bizard, from which it passes along the north side of the Island of Montreal, spreading out until it occupies the northern half of the island at Montreal. At St. Vincent de Paul it turns north and can be traced to St. Lin.

Black River and Trenton Limestones.—This formation follows the Chazy from Pointe Claire to Isle Bizard, Isle Jesus, and thence to the southern part of the Island of Montreal, across the lower end of Isle Jesus and to St. Lin.

Utica Shale.—The Utica shales occur on the south side of the St. Lawrence opposite Montreal, as well as on St. Helen's Island, and outcrops at Point St. Charles. A patch of metamorphosed Utica shale occurs on the southern slope of Mount Royal near the Upper Reservoir.

Lorraine and Richmond.—These formations lie to the east of the Utica, the strata around St. Bruno being late Utica or early Lorraine, probably the latter, while the Lower Richmond is found at St. Hilaire Station.

The Silurian and Lower Devonian (including the Oriskany) are only represented as inclusions in the breccias associated with the Monteregian Hills.

Monteregian Intrusives.—Of the main intrusives of the Monteregian Hills, only the two western ones, namely, Mount Royal and St. Bruno, require mention here as the remainder of the group lie well to the east of the area under consideration in this paper.

Of these Mount Royal is, in all probability, a volcanic neck or plug; while St. Bruno has been described as a laccolith although the evidence is not conclusive.[1]

At St. Bruno there was a single intrusion of a basic rock (pyroxenite) consisting of "biotite, hornblende and augite with basic labradorite and olivine occasionally in considerable amounts." Mount Royal is chiefly composed of two distinct rocks representing at least two periods of igneous activity. The earlier (essexite) intrusion is composed of "Labradorite, reddish-violet augite, brown horn-blende

[1]Geology of St. Bruno, by J. A. Dresser, G.S.C. Memoir No. 7, 1910.

and brown mica, while olivine, titanite, apatite, and other accessories are often present; nepheline is present only in small amounts, while hauyne can occasionally be detected." The second intrusion, consisting of nepheline syenite, took place on the northern border of the essexite, and is composed essentially of orthoclase, nephelite, and green hornblende with small quantities of plagioclase, pyroxene, garnet, and nosean with other accessory minerals.

At St. Bruno, and more particularly at Mount Royal, the intrusions were followed by the formation of great masses of breccia in sheets and dykes, including fragments of the sediments surrounding the igneous core; also there are complementary sets of dykes cutting all the earlier rocks and one another.

The breccias have been investigated by Dr. Harvie, who describes occurrences from the west side of St. Bruno, St. Helen's Island, and Isle Ronde in the St. Lawrence River opposite Montreal, from St. Paul Street, and the site of the Medical Building of McGill University in Montreal, and also on the north-east end of Westmount Mountain. West of Montreal, breccia is found in numerous localities, namely, at the White Horse Rapids in the Riviere des Prairies, at several places on Isle Bizard, and on the eastern slopes of the Oka Mountains at La Trappe. To these may be added an exposure of breccia near St. Anne de Bellevue, described by Logan, and two mounds to the north-west of Ste. Dorothée, on Isle Jesus, which are described below.

Harvie notes in his paper (p. 277) that: "An important fact revealed by the petrographic study is that in every case the cement of the breccia was in a molten condition both before and after the inclusion of the fragments. . . . The peculiar position of the blocks which are the sole representatives of the Helderberg and Oriskany in this district, has been the source of frequent speculation. Since it has now been shown that the paste was in a molten condition when it enclosed the fragments, and that the breccia, as a whole, has acted as an intrusive, the explanation is rendered comparatively simple. The breccia represents the truncated pipe or outlet of a reservoir of molten material, which outlet may have reached the surface and even formed a subsidiary cone to Mount Royal, or else it may have been of the nature of a laccolithic mass not opening on the surface. In either case, the intrusion extended up into the Helderberg and Oriskany, which must have overlain the Utica . . . ," He also shows that as the breccias of Isle Bizard and Westmount Mountain contain inclusions of an altered product of the essexite, they are later than the essexites.

The paste of which these breccias are composed is, as a general rule, alnoitic in character, and it is, therefore, natural to expect occurrences of alnoite near by. This is indeed the case, as at several localities to the west of Montreal there are intrusions of alnoite. As these occurrences are described more fully below, it is unnecessary to refer to them further at this point.

The fact that these breccias and minor alnoite intrusions are found to the west of St. Bruno and in increasing number to the west of Mount Royal might indicate that they are also present in connection with the other intrusions, but have not yet been discovered. On the other hand, it is observed that the western members of the main series of intrusives were, in all probability, active volcanoes, whereas the eastern members are laccolithic in character, and, therefore, it might be expected that the magma was much closer to the surface at the west than towards the east and that these minor intrusions have accompanied volcanic activity in an area whose overburden was comparatively light, compared with that above, let us say, Shefford and Brome. However, this thickness must have been considerable even at Mount Royal as the Lorraine alone attains a thickness of over 2,000 feet, and the Oriskany must have been considerably above that formation.

On the other hand, the western intrusives are found to be more basic in character than those towards the east, and these basic magmas, being more fluid than the acid magmas, may have been able to penetrate the rocks much more easily, both laterally and vertically, and thus give rise to these outliers and also to such phenomena as the intrusions of igneous breccia.

Quaternary

Pleistocene.—In glacial times the whole area was covered by a thick mantle of boulder clay or unstratified glacial drift.

After the glacial period, there was a period of submergence of the St. Lawrence Valley to a height of approximately 690 feet during which the morainic material was reworked and the Leda clay and the Saxicava sand were deposited on the shores of the epi-continental Champlain Sea. Uplift followed with a series of pauses, as is evidenced by the beaches found at various elevations around the City of Montreal and the valley of the Ottawa River.

Petrographical Descriptions

Monticellite Alnoite, Como, Que.

About one-half mile south-east of Como Station (29.9 miles from Montreal on the Canadian Pacific Short Line to Ottawa) a low elliptical mound rises to the south of a small stream running parallel with the railroad. It is composed of alnoitic rocks which outcrop within an area approximately 600 yards long by 250 yards wide; the long axis lies north-east and south-west parallel to the road running south-west from the river road near Como, and the exposure is bounded on the north by the small stream.

The mineralogical composition of the various types on monticellite alnoite at Como is as follows:

		Principal or Porphyritic type	Fine-Grained Variety	Eastern Exposure
Earlier Constituents (Usually as Phenocrysts)	Chrysolite-Monticellite	a	a	a
	Augite	b	a	b
	Biotite	aa	aa	a
Later Constituents	Chrysolite	b	b	...
	Biotite	b	b	...
	Monticellite	b	b	...
	Melilite	a	a	a
	Calcite	b	c	a
Accessory Constituents	Black Iron Ore	c	c	c
	Perovskite	c	c	c
	Apatite	c	c	c

aa Very Abundant
a Abundant
b Subordinate
c Present

As at Isle Cadieux, there are textural variations in the rock, the principal type containing porphyritic biotite occupies the greater part of the intrusion, while on the north and south sides of the exposure the fine grained minette-like type, similar to that noted by Bowen at Isle Cadieux, can be found in which the mica is less than one millimetre in diameter. The relations between this type and the principal type could not be determined owing to the paucity of outcrops.

Principal or Porphyritic Type.—The principal rock type of the exposure is a dark grey fine-grained rock which is plentifully speckled by poikilitic biotite crystals up to 5 mm. in diameter. This rock is slightly finer than the principal type described by Bowen at

Isle Cadieux. Outlines of augite crystals which attain a diameter of over a centimetre are present. These phenocrysts are almost completely resorbed, leaving only the outlines, while the interior consists of mica and the indeterminate groundmass. In some individuals traces of the original cleavage are quite plainly visible. Altered olivine phenocrysts are also not uncommon. The weathered surface is light brown in colour, and flakes of mica are plainly visible. This weathering is quite superficial and the rock appears to be quite fresh within half an inch of the surface.

Under the microscope the principal type was found to consist of phenocrysts of chrysolite, augite, and biotite, all of which have been greatly resorbed, followed by the formation of monticellite, biotite, melilite, and carbonates. Opaque iron ore, perovskite, and apatite are present as accessories.

Biotite is the most abundant constituent in the rock. It is light in colour, the deepest shade being a dark buff, indicating that the mineral is low in iron.

Some of the biotites present have idiomorphic outlines and are quite fresh, while others are embayed and are considerably altered and the rims of the laths and flakes in which the mineral appears have been bleached and are practically colourless. This, together with the fact that the birefringence of basal sections is below .008, would indicate that the mineral is rich in alkalies. Iron ore and perovskite occur scattered throughout the mica, and the colourless portions are not always confined to the rims but are occasionally found within the grains, in which case they are usually bounded by cleavage cracks in the parent mineral. The idiomorphic mica, which is very slightly or not at all altered, forms probably a second generation of mica, while the earlier poikilitic flakes have been considerably resorbed. One individual possessing a regular hexagonal outline and which is 0.5 mm. in diameter has a regular border of colourless mica, only 0.01 mm. in width. The mica is nearly uniaxial in character.

Chrysolite is present in two forms, probably representing different generations. Those of the earlier generation are irregular in outline and are frequently altered along cracks. Hydrated iron oxide is one alteration product, and usually the mineral is surrounded by a rim of monticellite. The difference in birefringence and the fact that the monticellite is distinctly negative in character render the identification of the two olivines comparatively simple. The chrysolite apparently contains about 10 per cent FeO as the angle 2V is practically 90°.

Frequently the chrysolite occurs in small grains surrounded by a rim of monticellite, and the whole is in turn embedded in a carbonate which is probably calcite; the inner part, however, is quite fresh.

Some idiomorphic crystals of chrysolite were also observed attaining dimensions of 0.5 by 1.0 mm. One was found abutting against a fragment of unresorbed biotite, and was deformed at the other end by a fragment of chrysolite which had partially altered to monticellite. These individuals probably represent a second generation of olivine.

Monticellite occurs, as a rule, in irregular grains up to 1.5 mm. in diameter as well as rims about the chrysolite. Its outstanding characteristics have been described above.

Melilite is an important constituent of the rock, forming a large part of the groundmass. It occurs in laths 0.2 by 1.0 mm. in size. These laths occasionally exhibit the characteristic peg structure of melilite and are, as a rule, negative in character. The basal cleavage is quite distinct in some individuals. Larger individual grains of melilite also occur. The mineral is closely associated with calcite and frequently is entirely surrounded by the latter mineral. The melilite itself, however, appears to be quite fresh.

Augite is comparatively rare in the rock, only a few scattered grains are found.

Black iron ore occurs in regular crystals and irregular grains and is included in all the older minerals. Part appears to be primary while a great deal has been derived from the alteration of augite and biotite. Many grains apparently contain a centre of pyrite, and pyrite occasionally occurs along minute cracks. The grains have a maximum diameter of 0.2 mm.

Perovskite is present in considerable amount and usually occurs in minute squares or octahedra. Like the iron ore, it is included in all the other minerals but less frequently in the minerals of the older generation, namely, the chrysolite and augite.

Apatite is present in minute laths and hexagonal sections.

The carbonates which are mainly calcite have been referred to above and consist of irregular grains surrounding mineral grains or filling interstitial spaces. They are very seldom associated with the earlier minerals, but, as has been noted above, frequently surround melilite and monticellite, forming with the former the bulk of the groundmass. It may be supposed that the carbon dioxide was introduced by ascending solutions after the final solidification of the rock. The occurrence of calcite in these basic rocks will be discussed more fully under the Ste. Monique occurrence, where its development can be traced in more detail than in the other areas.

The rock, therefore, has crystallized in two generations, as follows:

	Some resorption apparently and a second crystallization as follows:
Magnetite	Chrysolite
Perovskite	Biotite
Apatite	Monticellite
Chrysolite	Magnetite
Augite	Melilite
Biotite	

Thus the rock is a monchiquite which has altered during the process of cooling to a monticellite alnoite. The way in which these later minerals were formed and the nature of the magma from which they were derived has been fully discussed in Bowen's paper on the Isle Cadieux occurrence, with the exception of the calcite.

The Fine-Grained Variety.—The fine-grained variety consists of the same minerals as the principal type although there are some minor variations in their associations and manner of occurrence. The mode of alteration and resorption of the augite and chrysolite can be more clearly ascertained as the rock is fresher than that comprising the principal type.

One large augite grain (1.5 by 3 mm.) with rounded outline was observed. This grain is slightly brownish in colour, with a pleochroism so slight that it could not be determined. The mineral displays a perfect cleavage along which no alteration has taken place. Cracks are lacking, but iron ore and perovskite grains about 0.01 mm. in diameter are arranged along lines or forming sprays with no apparent regularity as to direction. Around the border there is a practically continuous rim of magnetite and perovskite, and outside of this border is an arrangement of biotite and melilite laths forming a wreath about the large crystal.

Other individuals have been altered along cleavage cracks to biotite. In these cases the rim of magnetite and perovskite is present, but there are few inclusions in the interior of the grain. In the majority of cases, the augite is in small grains, in groups consisting of several individuals in optical continuity, separated from one another by laths of biotite and melilite exhibiting a tendency to flow structure. In places, neighbouring grains are oriented at a small angle to one another, showing the possibility of some slight movement after the partial resorption of the original crystal of which these fragments are undoubtedly the remains. The iron ore is frequently arranged in clusters about these groups of augite crystals and as sprays connecting the grains.

Judging from the single individual noted above, it appears as if the augite was originally rich in titanium and iron. These constituents were leached out from the mineral, the former with lime, and recrystallized along certain indefinite lines within the crystal. It appears, then, that the crystals were resorbed in a solution rich in lime and alkalies which recrystallized, on cooling, to biotite and melilite, leaving a few remnants of the original crystal untouched.

Chrysolite also occurs in comparatively unaltered grains up to 0.5 mm. in length and in groups of partially resorbed individuals. The resorption phenomena noted above are also present in the case of chrysolite excepting for the formation of perovskite and iron ore.

It thus appears as if the original magma crystallized, partly at least, as augite and chrysolite. These crystals were partly resorbed by a magma rich in lime and the alkalies, especially the former, resulting in the formation of a later group of minerals consisting of biotite, melilite, monticellite, and probably magnetite and perovskite, although these last minerals may have been, to some extent, the first products of crystallization of the magma.

Biotite is the most abundant constituent of the rock and occurs in irregular flakes and occasionally rounded grains. The rounded grains are comparatively free from iron ore and perovskite, and may have been primary along with the augite and chrysolite. The flakes are associated with melilite and iron and titanium minerals and are undoubtedly of the second period of crystallization. These flakes are about 0.2 by 0.5 mm., and in places occur in an irregular congregation mixed with perovskite and magnetite. Where associated with melilite there is an incipient flow structure as noted above.

Melilite occurs in laths with dimensions of about 0.02 by 0.05 mm. and is associated with the biotite as noted above and also forms a large proportion of the groundmass. It is characterized by its low birefringence and indefinite optical character. The laths are zoned longitudinally, the outer zones having the lowest birefringence. The basal cleavage is indiscernible.

Monticellite is present in very small amount and usually occurs as widely scattered individuals, not in optical continuity. The resorption rims about the chrysolite are not so conspicuous as in the principal type described above.

Magnetite and perovskite occur in minute grains and very thin plates, the latter usually forming squares and octahedra.

Eastern Exposure, Como, Que.—At the sign post, one mile east of Como Station, the railway cuts through a hill strewn with more or less rounded blocks of alnoite No outcrops that could be definitely assumed to be in situ were found, but from the character of the hill, and from the absence of boulders in all parts of the surrounding area, it was assumed that this is another occurrence of alnoite similar to that half a mile to the west and also at Isle Cadieux.

The rock in the hand specimen is very similar to the non-porphyritic varieties at Isle Cadieux and Como, and consists of a dark grey, fine-grained rock in which the only mineral that can be distinguished is biotite which occurs in tiny grains up to 2 mm. in diameter.

Under the microscope the rock also resembles the neighbouring alnoites and consists of grains of augite, bleached and partially resorbed biotite, and chrysolite, which has been partially replaced by monticellite; there are also grains of monticellite in a groundmass of melilite and carbonates with black iron ore and perovskite as accessory constituents. The chief difference between this rock and those described above, and from Isle Cadieux, lies in the fact that the biotite is much fresher than at these other localities. Chrysolite is more abundant than augite, and monticellite is present both as resorption rims about the chrysolite and also as small hypidiomorphic grains.

Melilite, perovskite, apatite, and iron ore are present in about the same proportions as at Como.

Chemical Analysis of Monticellite Alnoite, Como, Que.
Analysis by W. V. Howard

		Norm	
SiO_2	30.27	An	8.06
Al_2O_3	10.00	Ne	6.82
Fe_2O_3	4.88	Kp	9.80
FeO	6.95	C	1.43
MgO	20.11	Ol	38.57
CaO	14.73	Cs	11.77
Na_2O	1.49	Mt	7.19
K_2O	2.85	Il	5.32
H_2O	2.17	Ap	2.35
TiO_2	2.84		
MnO	0.16	CO_2 equivalent to 7.40% $CaCO_3$	
P_2O_5	0.95		
CO_2	3.24		
	100.64		

Classification
Dofemane
dopolic (Scotare)
perolic
domiric
domagnesic
IV. 2. 5. 2."2

Spec. grav. 3.04

Monchiquite Sheet, Ste. Monique

At Ste. Monique, two miles north of St. Augustin Station, on the Canadian Pacific Railway, North Shore Line between Montreal and Ottawa, there are several outcrops of rocks similar in appearance to the alnoites at Isle Cadieux and Como. These exposures extend over an area about two miles long and half a mile wide; the southern exposure is situated on the west side of the road from Ste. Monique to St. Augustin Station about half a mile south of Ste. Monique, while the northernmost one lies a quarter of a mile east of the road to St. Jerome, and a mile and a half north of Ste. Monique.

Starting at the northern exposure, the following rock types are noted: The northernmost exposure forms the northern slope of a small hill and is 400 yards in length from east to west, by 100 yards in width. This is composed of a dark grey, fine-grained rock with coarse biotite grains up to 6 mm. in diameter. This locality is particularly interesting in that the rock contains small veinlets of calcite and biotite. These tiny veins are usually less than two millimetres in width and several centimetres in length and traverse the rock in all directions. In places, small patches of calcite a couple of millimetres in width and two centimetres in length, occur in the rock, not as veins, but as a primary constituent of the rock itself. The large olivine and augite phenocrysts which are characteristic of the alnoitic rocks of Como and Isle Cadieux are not present in this locality.

Thirteen hundred yards to the south is a similarly situated exposure which crosses the St. Jerome Road. This occurrence has a crescent-like outline, with the convex side towards the north, and is 600 yards in length by 75 yards in width. Here the coarser principal variety grades into the finer grained minette-like type, the latter occurring as sheet-like bodies two or three feet in thickness in the coarser principal type. There is no clear-cut contact between the two phases and they are simply textural variants of the same rock.

The next exposure lies 250 yards to the south and is a small knoll around which the St. Jerome road curves on the east side. Two hundred yards to the east of this last exposure is another small hill whose northwest slope is composed of similar rocks. In these two outcrops the fine and coarser types both occur.

Around the village of Ste. Monique and to the south, the whole area is strewn with boulders of monchiquite, and in the outcrops, several of which occur, both types are found although the coarser principal type predominates. In the southernmost exposure 800 yards to the south of the village the fine grained type is lacking.

This description of the outcrops from north to south is not intended to show any particular gradation as the source of the sheet is unknown. The exposures are simply described in the order in which they were visited.

As all these exposures cover a comparatively small area it is believed that they represent portions of a sheet which originally covered the area within whose limits the present outcrops appear. The roughly horizontal banding of the two types where these are associated together is also significant. The greater part of the sheet was removed by erosion and the remnants acted as a resistant barrier to the eroding action of the ice-sheet and protected, to a certain extent, the softer sedimentary rocks lying immediately to the south.

The mineralogical composition of the various phases of the monchiquite at Ste. Monique is as follows:

		Principal or Porphyritic Type	Variations in principal or Porphyritic Type	Fine-grained Type
Earlier Constituents (Usually as Phenocrysts)	Augite	b	b	b
	Chrysolite-Monticellite	a	a[2]	aa
	Biotite	b	a	a
Later Constituents	Monticellite	b	b	b
	Poikilitic Biotite	aa	....	b
	Calcite	b[1]	b	b
Accessory Constituents	Perovskite	c	c	c
	Brookite	c	c	c
	Black Iron Ore	c	c	c
	Apatite	c	c	c

aa Very abundant
a Abundant
b Subordinate
c Present

Principal or Porphyritic Type. — The principal or porphyritic type whose megascopical features are described above, is found to consist of phenocrysts of augite, chrysolite, and biotite in a groundmass of monticellite, biotite, and calcite, with brookite, perovskite, apatite, and opaque iron ore as accessory constituents.

Augite is present in very small amount and is of the colourless variety. It occurs as regular idiomorphic crystals, up to 0.2 mm. in length, and has undergone only a slight amount of alteration along cracks. The extinction mounts to 45°.

Chrysolite is an abundant constituent of the rock, and under ordinary light has, as a rule, regular idiomorphic outlines. The crystals are about 0.3 mm. in length and are usually prismatic and terminated at each end by a dome which may or may not be truncated by a basal pinacoid. Under crossed nicols, it is found that frequently the chrysolite occupies only about fifty per cent of the grain, while the exterior is composed of monticellite. Inclusions of iron ore, perovskite, and brookite are common. The chrysolite is frequently enclosed by biotite, and here the monticellite border is lacking or

[1]Calcite occurs in small veinlets.
[2]The alteration to monticellite is less strongly marked in this phase.

very small, and the grain is allotriomorphic. The mineral is distinctly positive and is, therefore, poorer in iron than the Como chrysolite whose optical character was difficult to determine.

Monticellite is present as resorption rims about the chrysolite, as has been described above, and also occurs as prismatic laths attaining dimensions of 0.1 by 0.3 mm. It is usually hypidiomorphic in outline, but occasionally occurs as regular crystals terminated by domes. Besides occasional magnetite grains, it contains minute grains of calcite. In places it is found as chadacrysts in the biotite, in regular crystals, although usually the phenocrysts occur throughout the rock with no definite mineralogical associations.

Occasionally this mineral appears in the groundmass and where it is in contact with the biotite this contact is usually a straight line, although otherwise the grains are decidedly allotriomorphic. It, therefore, appears as if the monticellite had begun to crystallize before the biotite, but had continued until the formation of this mineral was completed.

Biotite, the most abundant mineral present in the rock, occurs in two generations. The earlier generation consists of small hypidiomorphic grains, 0.2 by 0.4 mm. These are often included in the poikilitic biotite which constitutes the second generation, and often partially enclose phenocrysts of olivine. The only inclusions noted are iron ore and perovskite.

Most of the mica present in the rock is present as oikocrysts, that is, as host minerals possessing poikilitic fabric, and with very irregular outlines, except when in contact with the monticellite as noted above. It is often as much as 2 mm. in length and it is usually found that several of these irregular masses are in contact with one another and form roughly a single individual. In these cases, the contact is very uneven, and usually the two grains are in close contact without any intervening minerals. The contact would be indiscernible if the two individuals happened to be in optical continuity, and it is quite possible that some of the larger grains are composed of two individuals which happened to be oriented in the same direction when they crystallized from the magma. As a matter of fact, some grains were found to show slightly different interference figures at either end, although, judging from their cleavage, pleochroism, and extinction, no deformation could be observed. If these were originally two distinct crystals which grew together in this way, the exact contact could not be found.

The poikilitic variety contains grains of the iron and titanium accessory minerals as well as laths, tabular crystals of monticellite, and corroded grains of olivine.

The biotite is deep brown in colour and is strongly pleochroic, while the bleached border so noticeable in the Como occurrence is, to a great extent, lacking. The mineral appears to contain more iron than the Como variety as it is much deeper in colour.

Iron ore, perovskite, and brookite occur in minute crystals, the last two usually idiomorphic. The titanium oxide present is a light wine red in colour and occurs in minute squares. As the grains were too small to show an interference figure, or indeed to show even the order of the birefringence, its identification as brookite is somewhat uncertain. It has, however, a very high refractive index and birefringence and no apparent cleavage. These facts, together with its occurrence in squares, led to its identification as brookite, since rutile and anatase, with which it might be confused, have altogether different crystal habit.

Perovskite occurs in the typical wine yellow squares and octahedra with high refractive index and is isotropic.

Calcite is not present in large quantities except along the tiny veinlets noted above. In the fresh rock it occurs in very small grains, usually within monticellite or in the hypidiomorphic biotite crystals where it frequently occupies about fifty per cent of the grain and is situated at the centre. The minerals in which it occurs are otherwise quite fresh and there is practically no trace of serpentinization of the olivine or other products of weathering. The nature of this calcite is described more fully below, as its development is more clearly shown in other parts of the rock.

The order of crystallization of the rock thus appears to be as follows: After the formation of the iron and titanium accessory minerals, chrysolite and augite, the most basic ferro-magnesian constituents of the rock, crystallized out. These minerals became partly resorbed by the residual calcic-alkaline magma and there was also a partial replacement of the chrysolite by the lime olivine, monticellite. Thus, the formation of monticellite probably followed the chrysolite very closely. The olivines were subjected to further resorption, while monticellite and the earlier generation of the biotite were crystallizing out. This stage was followed by the final crystallization of the monticellite which appears in the groundmass together with the large poikilitic biotites. Whether the calcite is also a product of this final solidification or not will also be discussed below, but anticipating this discussion a little, it may be stated that, in the opinion of the writer, at least, it was formed by solutions ascending through the magma after it had completely cooled.

Variations in Principal or Porphyritic Type.—In the southern part of the sheet there are few deviations in the mineralogical composition of the principal type, and megascopically the rocks are similar in appearance.

The first minerals to crystallize were, as before, brookite, perovskite, and black iron ore. The iron ore is in rather irregular grains, but the brookite and perovskite, as described above, crystallized in minute squares and octahedra.

Regular idiomorphic crystals of chrysolite and colourless augite are present, the former in relatively larger amount than the latter. Chrysolite often occurs as rounded grains enclosed in larger biotite crystals.

Biotite occurs in hypidiomorphic individuals, usually with one or more straight edges, and is lighter in colour than in the type described above. Inclusions of all the above accessory and idiomorphic minerals are common, and the contact between biotite and monticellite is usually characterized by straight edges. This mineral is still the most abundant constituent of the rock, but does not exceed all the other constituents as it does in the principal type. The poikilitic variety is not nearly so prominent nor are the separate individuals in close contact as a rule.

Monticellite usually occurs in hypidiomorphic prisms, although the majority of the crystals of chrysolite have a very narrow border of a mineral with lower birefringence which was taken to be monticellite.

Besides the above regular forms, there is a coarse groundmass consisting of monticellite and carbonate.

The monticellite present in the groundmass forms irregular fragments filling the interstices between biotite and other minerals such as chrysolite, and, from its relations with the biotite, it appears as if it had begun to form before the formation of the biotite and had continued after the latter had been completely crystallized from the magma.

Calcite also occurs in the groundmass in irregular masses and is very probably a product of hydrothermal action. Veinlets of calcite, such as are described above, are lacking here, but as the olivine is extremely fresh except for the border of monticellite, indicating slight resorption, it is difficult, if not impossible, to dismiss the calcite simply as a product of weathering.

The minor differences between this type and the principal type appear to be due to a lesser degree of resorption, possibly owing to slightly more rapid cooling.

Notes on the Occurrence of Calcite.—Although there is a great deal of calcite in all the sections examined from this area, no trace of the partial carbonatization of any primary constituent was noted, although irregular grains of calcite are frequently included in the hypidiomorphic grains of biotite. It cannot be assumed that in every case, where carbonatization has begun, it has been carried to completion and no trace of the original mineral can be found, excepting in these biotite grains. Chrysolite, which is often closely associated with the calcite, is quite fresh. Calcite was never definitely recognized as a pseudomorph and, where present, always occurs as irregular grains with inclusions of perovskite, brookite, and iron ore, and frequently encloses idiomorphic olivines which have a narrow border of monticellite, but show no other form of alteration. It, therefore, seems necessary to find some explanation for the presence of calcite other than to state that it is simply a product of weathering.

Sections cut along the small veinlets consisting of biotite and calcite show a peculiar alteration of the biotite. In places, radial spherulitic aggregates of fibres occur which, in ordinary light, are colourless, and have a lower refractive index than the biotite. With crossed nicols they have a low birefringence, and possess the aggregate polarization of chlorite. All variations are seen, from the incipient fibrous material which has the same colour as the mica and is not distinguishable from the biotite in ordinary light, to small areas having an idiomorphic outline, and composed of small aggregates of chlorite. Some of these areas, however, contain calcite in place of chlorite. These areas occur along the plane of symmetry of the biotite and appear to have been originally cavities in the mica.

Thus, after the solidification of the rock, cracks were formed and these cracks were filled with biotite and calcite. Later ascending solutions partially altered the biotite to chlorite and any cavities remaining were filled with calcite. Whether the calcite found throughout the rock is due to hydrothermal action or is primary, it is impossible to say.

Fine-Grained Variety.—The fine-grained material which is merely a textural variant of the principal type is more equigranular owing to the absence of poikilitic biotite, but otherwise is very similar in mineralogical composition.

Chrysolite is by far the most abundant constituent, and almost invariably occurs as regular prisms terminated by domes. These crystals are usually not more than 0.5 mm. in length, and are, as is usual in these rocks, partially replaced by monticellite about the borders.

Augite is also present in idiomorphic individuals but to a smaller extent than the chrysolite.

As before, monticellite occurs as hypidiomorphic grains, as resorption rims about the chrysolite, and also in the groundmass.

Biotite is present as allotriomorphic individuals, and shows the same associations with calcite and monticellite as before. The accessory minerals, brookite, perovskite, and black iron ore again occur, and the groundmass is composed of monticellite, and calcite.

General Statement.—The rock is, therefore, composed essentially of phenocrysts of olivine, augite, and biotite in a groundmass consisting of monticellite. If this groundmass contained melilite, the rock would be a typical alnoite, whereas if the groundmass were analcite or glass, it would be classed with the monchiquites. To introduce a new term would serve no purpose other than to overburden an already voluminous nomenclature, and the rock will simply be termed a monchiquite.

After the formation of the iron-titanium accessory minerals and the ferro-magnesian constituents, the magma contained a large proportion of the lime and alumina and a considerable amount of carbon dioxide. The chrysolite was partially resorbed in this magma, giving rise to a partial replacement by monticellite, while calcite and chlorite were formed later, by hydro-thermal action.

Chemical Analysis of Monchiquite, Ste. Monique, Que.
Analysis by W. V. Howard

SiO_2	31.63
Al_2O_3	10.60
Fe_2O_3	4.56
FeO	6.42
MgO	17.82
CaO	17.16
Na_2O	0.61
K_2O	2.48
H_2O	0.93
TiO_2	2.44
MnO	0.12
P_2O_5	1.09
CO_2	4.92
	100.78

Norm

An	18.63
Ne	2.84
Kp	8.53
Di	6.54
Ol	32.22
Cs	6.10
Mt	6.73
Il	4.56
Ap	2.69

CO_2 equivalent to 11.10% $CaCO_3$

Classification
Dofemane
dopolic (Scotare)
domolic
domiric (Casselase)
domagnesic (Casselose)
″IV. 2. 4(5). 2. 2

Spec. grav. 3.16.

Breccias and Other Intrusives, La Trappe

The village of Oka lies on the north shore of the Lake of Two Mountains directly across the lake from Como; at this place there is a narrow fringe of Potsdam sandstone which is covered by a heavy overburden of drift, and which circles the Pre-Cambrian rocks of the Oka Mountains immediately to the north. Four miles north-east of Oka is the Monastery of La Trappe which lies on the south-eastern border of these mountains.

Several occurrences of breccia and basic intrusives of undoubted Monteregian character cut the Grenville limestones and quartzites in the vicinity of the monastery. These have been briefly described by Harvie, and his paper is frequently quoted in the following description of the occurrence and the relationships of the rocks of which it is composed.

The mineralogical composition of the basic intrusive at La Trappe and the associated dykes is as follows:

	Biotite Peridotite	Western Dykes I	Western Dykes II	Eastern Dyke
Olivine	a		b	a
Augite	b	a	a	a
Biotite	a	b	a	
Labradorite	b	b		
Accessory and secondary minerals:				
Magnetite	a	c	c	c
Natrolite	c			
Perovskite	c			
Apatite	c			

aa Very abundant   b Subordinate
a Abundant   c Present

Biotite-Peridotite.—The main intrusive in this vicinity forms a small hill, about 100 feet high and a quarter of a mile across, and is situated to the west of the ravine immediately west of the Monastery. Harvie[1] describes this hill as follows: "It is formed by an intrusive plug which has pierced the Grenville Limestone and Laurentian gneiss near the contact of the two. The main mass is almost pure intrusive material but the border zone is a breccia formed from the gneiss, limestone, and Potsdam sandstone. The Grenville is shot through with stringers of the igneous material and there are several

[1] *Op. cit.* pp. 256-258.

large offshoots running away from the hill on the north side. Several dykes of a camptonite-like rock cut these outliers where they cross the highway . . ."

Megascopically, the rock presents considerable variation. In the centre the rock is composed of phenocrysts of augite, olivine, and biotite in a dark grey groundmass. The augite occurs in large individuals up to half an inch in diameter, and is black in colour. Pale green olivine is found in huge phenocrysts commonly an inch across, and biotite occurs in large irregular crystals, up to half an inch in diameter.

In the groundmass itself there are a large number of small white grains, commonly a couple of millimetres in diameter; these appear to be largely composed of calcite, but in many cases have a dark centre of augite or olivine. They appear to be the remains of small olivine and augite crystals which have been partially resorbed and although it is not so noticeable in the larger individuals, close examination shows the same resorption about the border.

Harvie found the rock to consist of phenocrysts of augite and olivine, two generations of biotite, labradorite, two generations of apatite, ilmenite, pyrite and pyrrhotite, perovskite, a zeolite considered to be natrolite and a base of nepheline as well as two unknown minerals. Of these the former was "at first taken for apatite. . . . It has the same low refraction, dull polarization and colour, but is monoclinic, with an extinction up to 43°. A second unknown mineral also occurs in small amount, being well preserved as short prisms with good outlines, showing slight cleavage, and having an inclined extinction up to 45°. It has a refraction distinctly higher than that of calcite and polarizes in dull to pale yellow tints."

These minerals were not all found by the writer but it must be pointed out that the Monteregian outliers described in this paper are all of very variable composition, and it is quite probable that sections from other parts of the same outcrops would in many cases show different mineralogical compositions from those described. This outlier at La Trappe does indeed present several different facies whose relationships with one another are masked by a heavy blanket of drift, so that no division into a principal phase and subordinate variations can be made. The writer will content himself simply with describing what he considers to be the most characteristic type present, together with some facies which appear to be transitional between this type and the breccias, and which are represented by several dykes and outliers in the neighbourhood. It must, however, be understood that other investigators visiting this area may find still other minerals that were not found by their predecessors.

The rocks collected by the writer from this place were examined in thin section and are composed of olivine, augite, and biotite, all very much altered, with rounded grains of labradorite and apatite in a fine-grained groundmass. The accessory minerals consist of magnetite, ilmenite, pyrite, pyrrhotite, and perovskite, most of which appear to be of secondary origin as they do not occur to such an extent in the fresher rocks described below. Serpentine, calcite, and a semi-opaque mineral very similar to leucoxene are undoubtedly secondary. Amygdules filled with natrolite also are present.

Magnetite.—A most striking feature of the rock is the large grains of black iron ore present. These grains are often over three millimetres in diameter, and are frequently surrounded by a number of smaller grains. Owing to the absence of leucoxene around these grains and the fact that TiO_2 is not abnormally large in the rock, this mineral is supposed to be largely magnetite, although some ilmenite is undoubtedly present. Besides the clusters about the larger grains, small grains of magnetite are scattered throughout the rock and there is a rim of magnetite about 1 mm. in width around the flakes of biotite. This association is described more fully below.

With the magnetite is associated pyrite and pyrrhotite, either in small separate individuals or speckled through the larger masses of iron ore.

There are two varieties of olivine present, one apparently richer in iron than the other, and further variation is noted in the decomposition products of the two varieties.

An iron-rich olivine occurs as large grains and is colourless but feebly pleochroic, in pale yellowish tones, C being colourless. The birefringence $\gamma-\alpha=.050$, and $\gamma-\beta=.010$; the mineral is biaxial and distinctly negative in character. Olivine which is apparently slightly different in composition from this pleochroic variety is also present. It has a slightly lower birefringence and is non-pleochroic. This variety is invariably surrounded by a semi-opaque rim of alteration products, and is rarely distinguishable in the hand specimen, while the pleochroic variety is fresher and is transparent in the hand specimen.

The iron-rich variety which occurs in large grains, several millimetres in diameter, is surrounded by a uniform border, about 0.1 mm. in width, of a mineral which is very similar to that forming the bulk of the groundmass. Iron ore is absent from this border, with the exception of a few minute grains along the interior. The border is composed of minute grains of a colourless non-pleochroic mineral which has a refractive index slightly lower than that of the olivine. These grains are rarely over 0.03 mm. in diameter, and are closely packed together, although a tendency to alignment normal to the edges of the olivine is noticeable. The highest interference colour observed is a deep yellow of the first order, making the maximum birefringence about .011, or slightly below that of monticellite. The mineral is biaxial and negative, and there is a very poor cleavage, which may be simply tiny irregular fractures. If this is the case the mineral can be assumed to be fibrous serpentine and the olivine from which it has been derived therefore contains some magnesia. The interior of the olivine is quite fresh, and there is practically no alteration of any kind even along the cracks.

Throughout the groundmass there are small grains of olivine less than 0.1 mm. in length surrounded by fibrous serpentine and the latter mineral is profusely scattered through the rock in small grains; frequently small areas are found in which the olivine has been completely altered to this mineral. The presence of these smaller grains of olivine and serpentine throughout the whole of the rock is very probably due to a grinding motion of some sort which ripped off fragments from the phenocrysts and scattered them through the magma. This action is also noted below in the case of the biotite.

The other form of olivine present is similar to the variety thus described, except that it is non-pleochroic and is surrounded by a semi-opaque border of a mineral resembling leucoxene. These rims vary greatly in character, and to describe them fully would require a detailed description of every individual of olivine present in the rock. Suffice it to say that these olivine grains, sometimes a millimetre in diameter, are surrounded by a narrow rim of serpentine, which is in turn enclosed by a rim about 0.35 mm. in width of a semi-opaque mineral which resembles leucoxene very closely, although it is not derived from ilmenite, and must, therefore, differ from leucoxene in composition.

It is quite within reason to suppose that the larger grains which are only surrounded at present by serpentine were formerly enclosed in a semi-opaque rim as well, but that this rim has been removed by subsequent motion within the magma.

Augite is present in variable amounts, and is of the ordinary variety. It is also surrounded by alteration rims very similar to those surrounding the non-pleochroic olivine.

A third mineral which exhibits to a certain extent the same alteration phenomena is biotite. This mineral is comparatively light in colour, ranging from a pale yellowish brown to light brown. The "biotite occurs in occasional large plates up to half an inch across surrounded by a dense border of magnetite grains. The forms are much corroded, and several instances show the reaction working into the heart of the crystal, the reaction being favoured by the strong cleavage of the mica." In the sections examined by the writer, although most of the individuals show this alteration, some are surrounded by a semi-opaque rim similar to those around the olivine and augite. Still others show no alteration about the edges and occur in very irregular jagged grains. The biotite in the groundmass is occasionally in optical continuity with neighbouring larger individuals, and it is suggested that these unaltered fragments were originally much larger, and were enclosed in a rim of magnetite and possibly also the semi-opaque material, but that this border together with some of the unaltered mica had been torn away, and that the fragments thus removed were scattered through the still liquid magma and, on the final solidification, formed a part of the groundmass.

Rounded grains consisting entirely of iron ore and the semi-opaque rim are common, as well as many grains of the semi-opaque material without the iron ore. It is thought that the former represent completely altered biotites, although it is possible that ilmenite was the primary mineral in which some trace of the cleavage still remains, while the latter are either wholly metamorphosed olivine or augite.

Other minerals present as phenocrysts are apatite, in irregular rounded grains, and small amounts of labradorite which is largely altered to calcite.

Natrolite occurs filling amygdules in places.

The groundmass is composed of a granular aggregate mainly of iron ore, biotite, and serpentine. Perovskite in minute grains is abundant.

The earlier minerals such as olivine, augite, and biotite appear to have formed while the magma was rising and their formation occupied a considerable period as the phenocrysts are quite large. After this partial crystallization conditions changed, the phenocrysts were partially resorbed in the residual magma, and in some way parts of the resorption rims and even of the unaltered minerals were removed by abrasion and scattered through the groundmass. It also appears as if the rock comprising this main intrusion represents more especially the earlier minerals and their alteration products, this speculation is correct, the more acid part of the magma was in all while the residual magma has to a great extent been removed. If likelihood forced upwards by the slow settling of these more basic constituents and concentrated in the breccia dykes.

As inclusions of crystalline limestone are noted in other parts of the neighbourhood, some of the calcite present may have been derived from inclusions of the country rock.

The rock as it is at present constituted can best be described as a biotite-peridotite, although it resembles an alnoite very closely except for the absence of melilite.

Western Dykes and Breccia.—Besides the main intrusion described above, there are several outcrops of breccias and associated dyke rocks, of which only two groups will be taken up here.

The first group consists of the breccia described by Harvie to the west of the main intrusion, a dyke which appears to be very closely associated with it, and a small intrusive mass on the road just west of the Monastery gates.

The breccia is situated a quarter of a mile to the west of the main intrusive and is "a dyke about twenty-five feet wide, which may be followed by occasional outcrops for a distance of half a mile." Although it cuts the Pre-Cambrian, it contains "fragments of Potsdam sandstone and one of a rock probably the Calciferous, both of which are stratigraphically higher than the gneiss." The groundmass is very similar to that of the dyke described immediately below, that is, it consists of an altered feldspathic rock with calcite and iron ore.

In the open field 250 yards north of the Oka-La Trappe road, near the bridge just west of the Monastery, a small dyke was found cutting the Pre-Cambrian quartzite. This dyke, in the hand specimen, is dull grey in colour and of a very fine grain. The only discernible minerals are minute flakes of augite, less than a millimetre in diameter, and occasional white grains of calcite.

This dyke is about one foot in width and has a strike of 240° and a dip of 60° to the northwest. It is exposed along twenty-five feet of its length, and breaks up towards the west into tiny stringers, finally disappearing within a few feet. Towards the east it is covered by drift.

A microscopic examination showed that the rock is composed of a network of laths of biotite and augite in a fine-grained groundmass and is very highly altered.

Augite is present as laths about a millimetre in length and 0.1 mm. in width in the largest individuals, the average being 0.2 by 0.04 mm.

In the larger laths twinning along 100, and the typical hour-glass structure of augite were noted. The mineral is comparatively fresh.

Biotite, which has been highly altered to chlorite and iron ore, also occurs in minute laths rarely more than 0.1 mm. in length, and 0.01 mm. in width. In places plates of mica are noted with a regular hexagonal outline, which have been altered to a brownish isotropic mineral, while the iron content has been leached out and forms clusters of irregular grains close to the altered mica.

These biotite and augite laths form a complicated network, and, with the iron ore, constitute the greater part of the rock. The groundmass is indeterminate in character, and has been greatly altered to calcite. It appears to have been originally a calcic feldspar.

This dyke is undoubtedly associated with the breccias to the west similar to the association between the breccias described in Harvie's paper and the accompanying lamprophyric dykes.

The next locality in this series is an irregular outcrop of basic rock, very similar in appearance to the main intrusive which lies on the north side of the road from La Trappe to Oka just west of the bridge near the Monastery gates. The contact between this irregular mass and the Grenville limestone is visible in places, and the limestone has been very much altered by the intrusive rock. Inclusions of limestone in the rock itself frequently occur.

In the hand specimen, the chief differences between this rock and the main type are that the phenocrysts of augite and biotite are neither so large nor so highly altered. Pyrite and pyrrhotite are present, and there are some patches of the latter mineral several inches in diameter. Although alteration has not proceeded to such an extent as in the main mass, there are a large number of round white grains a millimetre or so in extent, which have been derived from small augite and olivine grains.

In this section the freshness of the rock as compared with that of the larger intrusive is at once apparent, and the succession of minerals can be more readily determined owing to the relatively small amount of resorption and alteration.

The first mineral to crystallize was apatite, which occurs as small hexagonal crystals sometimes 0.3 mm. in diameter, as well as in long narrow laths up to 2 mm. in length and rarely more than 0.2 mm. in width.

Olivine entirely of the iron-rich variety is not so abundant as in the main intrusion, and is almost completely altered to iron ore and a semi-opaque mineral similar to the alteration product of the olivine of the principal exposure. Grains of calcite are also present within the original olivine grains, the limits of which are plainly visible.

Large idiomorphic augite crystals are abundant and are usually associated with the apatite as larger grains enclosing the hexagonal plates and long laths of the latter mineral. Augite, unlike olivine, is perfectly fresh and is greenish grey in colour, with a dark green to purplish grey pleochroism. It is, therefore, the titanium-bearing variety and thus, titaniferous augite is probably the source of the ilmenite and perovskite of the main intrusion.

Light brown biotite is an abundant constituent and exhibits strain shadows, indicating motion in the magma after partial crystallization. A light green mica, probably phlogopite, is also present, although in smaller quantities.

The groundmass consists of a granular aggregate of indeterminate character which has been largely altered to calcite, and grains of calcite are common throughout the rock.

Black iron ore is not so abundant as in the main intrusion where it is probably of secondary origin, and has apparently been derived from the olivine. The sulphides, pyrite and pyrrhotite, are abundant locally, although some sections contain very little of either mineral.

Just how much of the calcite is due to inclusions of the Grenville limestone and how much to weathering cannot be determined, but doubtless both have contributed a share of the carbonate present.

This exposure lies between the main intrusive and the dyke associated with the breccias and appears to be largely composed of the ferro-magnesian constituents of the magma, while the dyke is slightly more acid, and the paste of the breccia is apparently composed of the final products of crystallization. Therefore, it appears probable that in the surging of the magma during the formation of the breccia, the constituents which were the first to crystallize settled toward the parent mass.

In other words, the paste of the breccias, the dykes closely associated with the breccias, and outlying occurrences such as the one described immediately above, are not only associated in position, but are also differentiation products of the original magma. The earlier phenocrysts settled towards the main intrusive during the period while the still fluid acid part of the magma was brecciating the country rock through which it welled.

Eastern Dyke and Breccia.—A mile to the east of the Monastery is a breccia which is described by Harvie. Between this breccia and the Monastery on the small hill in rear of the buildings is a dyke about two feet in width cutting the Grenville limestones and quartzites.

This dyke is essentially the same as that described above from near the Monastery gates, except that olivine is much less abundant.

Large titaniferous augite crystals several millimetres in length predominate. This mineral has been partially resorbed and altered to sericite, calcite, chlorite, and iron ore around the borders and along cracks.

A deep greenish brown biotite is also present in irregular grains up to two millimetres in length. This mineral has not suffered so much alteration as the augite, but, apparently, fragments have been broken off and scattered through the groundmass together with augite and much of the chlorite which formed around the borders of the augite.

The groundmass is composed of these fragments of biotite, augite, and chlorite together with irregular grains of black iron ore and a base which has been totally altered to calcite.

This dyke may bear the same relationship to the eastern breccia as that on the road bears to the breccias west of the Monastery. That is, it may represent a part of the channel through which the magma forming the paste of the breccia surged and into which the ferro-magnesian constituents settled after partial crystallization.

Chemical Analysis of the Biotite Limburgite, La Trappe.
Analysis by E. P. Dolan

SiO_2	30.78	*Norm*	
Al_2O_3	1.49	Le	3 05
Fe_2O_3	5.64	Ne	2.27
FeO	10.34	Ac	6.93
MgO	16.35	Ns	2.81
CaO	22.02	Ol	36.98
Na_2O	2.85	Cs	23.99
K_2O	0.67	Mt	4.64
H_2O	0.98	Il	6.38
CO_2	2.78	Ap	5.04
TiO_2	3.33		
P_2O_5	2.07	CO_2 equivalent to 6.30% $CaCO_3$	
MnO	0.10		
	99.40	Classification	
		Perfemane	
		dopolic	
		domolic	
		calcimiric	
		domagnesic	
Spec. grav. 3.17		V. (1)2. 4(5). (2)3. 2	

Camptonite. Husereau Farm Near St. Benoit

A very interesting exposure lies about half a mile east of the intersection of the Ste. Sophie and Ste. Germaine Roads, about half way between the Monastery of La Trappe and the village of St. Benoit. This latter village is situated on the Canadian National Railway between Montreal and Ottawa. This exposure is undoubtedly related to the other basic intrusives described above, and is situated on the farm belonging to one Husereau, and for want of a better name will be referred to as the Husereau occurrence.

This occurrence cuts the Grenville series on the north-west side of a hill which rises about one hundred feet above the Ste. Sophie Road to the west. The intrusive is roughly circular in outline and is about 250 yards in diameter. By far the largest part of the intrusive is composed of a dark grey rock in which the most prominent feature is irregular plates of mica which are in places a centimetre in diameter. Small grains of colourless pyroxene can also be identified.

Two other phases are present around the border of the principal type. One is a light grey rock which appears to be composed almost entirely of nepheline, and the other, which is apparently a transition phase between the two, is a dark grey fine-grained rock with occasional small plates of mica, which possesses no other features which are distinguishable in the hand specimen.

The mineralogical composition of the various phases of the Husereau occurrence is shown below.

Essential Constituents	Principal Type	Nepheline Aplite	Transition Phase
Biotite	a	b	b
Augite	b	–	–
Diopside	b	–	–
Olivine	b	–	–
Andesine	b	–	–
Nepheline	b	a	b
Sodalite	–	b	–
Glass	b	–	a
Accessory Constituents			
Iron Ore	c	c	–
Apatite	c	c	c
Melanite	–	c	c
Pleonaste	–	–	c
Monticellite	–	–	c (?)

a Abundant b Subordinate c Present

Principal Type.—The larger part of the rock is composed of phenocrysts of pale biotite, augite, diopside, and olivine with a large amount of black iron ore in a granular groundmass which is very largely altered to calcite but contains some andesine, nepheline, and glass.

Biotite occurs in irregular grains and hypidiomorphic crystals which may be as much as a centimetre in length. The mineral is light greenish brown in colour, and the pleochroism is weak. The crystals are deformed in places indicating movement after partial cooling, and a small amount of resorption has taken place Some of the iron content has leached out giving rise to small grains of magnetite along the cleavage cracks and also around the edges of the grains.

Augite is present in equi-dimensional rounded grains from 1.5 to 2 mm. in diameter. It is slightly tinted in yellow and purple shades and contains inclusions of iron ore arranged along definite lines through the grains; clusters of iron ore around the augite are common. The purple tint indicates that the mineral is rich in titanium. Augite is the most abundant ferro-magnesian constituent present, the two next in order of abundance being phlogopite and diopside.

Diopside is found in subordinate amounts in irregular colourless grains about a millimetre in diameter. Some of these diopside grains are surrounded by a rim of iron-rich augite. In such cases, the interior of the grain extinguishes at $-44°$ and the bordering augite at $-56°$. This augite is colourless and tends toward the more sodic aegirite-augite. Frequently the border is equal in width to the unaltered interior. Alteration also proceeded along cracks in the diopside by means of iron-rich solutions, and the superfluous iron was deposited as black iron ore along the cracks and around the border.

Olivine is present in very subordinate amount and occurs as idiomorphic crystals up to 2 mm. in length and also in rounded grains surrounded by a rim of secondary minerals such as calcite and antigorite.

The groundmass is largely altered to calcite and other secondary minerals in minute grains, but andesine or acid labradorite and nepheline can be distinguished. The minerals forming the groundmass usually form rounded grains less than 0.5 mm. in diameter, and some isotropic grains which appear to be glass were observed.

Magnetite and apatite are present as accessories, the former in irregular grains ranging from less than 0.01 to 1.5 mm. in diameter.

It is largely of secondary origin. A few laths and hexagonal prisms of apatite are found sparsely scattered through the rock.

Cavities up to 1.5 mm. in length, filled with calcite, are common, and as the occurrence is apparently not closely connected with the breccias, there is a possibility that the carbonate may be to some extent of primary origin.

The rock is, therefore, essentially composed of augite, with subordinate biotite and diopside and very little olivine, in a groundmass of sodi-calcic feldspar, nepheline, and glass, and may be termed a camptonite with subordinate olivine, as nepheline-bearing camptonites have been described from different localities in Eastern America, associated with essexites and nepheline syenites.

Nepheline Aplite.—Besides the camptonite described above, there are also outcrops of a light grey coarsely crystalline rock which can best be described as a nepheline aplite, although orthoclase is absent.

In this section, the rock is found to be composed very largely of nepheline, which has partially altered to thomsonite, with subsidiary amounts of biotite and sodalite. A considerable amount of black iron ore is present as well as some apatite and melanite.

Nepheline with its alteration products make up fully 75 per cent of the rock. This mineral occurs in irregular grains up to a centimetre in length. Apatite and black iron ore are present as inclusions, the former in regular crystal forms up to 0.5 mm. in length, and the latter as minute grains scattered through the nepheline, and occasionally as lines of minute specks. In some individuals these lines are symmetrically arranged, and intersect one another at an angle of about 60°. In the majority of cases, however, these inclusions are arranged along the cleavage. The nepheline is also fractured, and alteration has taken place along these fractures and around the border, resulting in the highly birefringent zeolite, thomsonite.

Sodalite is present in rounded grains and is also partly altered to thomsonite. The alteration product is present in far greater quantity when associated with both nepheline and sodalite than with either of these two minerals alone.

Biotite occurs in very irregular flakes up to 0.5 mm. in length. It is light grey-brown to dark greenish-brown in colour and contains irregular flakes of black iron ore. This iron ore is usually associated with the nepheline and biotite, and always occurs in irregular grains.

Irregular and rounded grains of deep brown melanite are present. This mineral displays the zonal structure typical of garnets, and in places some of these zones are anomalously biaxial and negative.

Transition Phase.—The rock marking the transitional phase between the camptonite and the nepheline aplite is largely composed of glass with phenocrysts and rounded grains of melanite, pleonaste, nepheline, sodalite, biotite, and possibly monticellite.

Melanite forms a host of minute rounded grains which are light green to light brown in colour. These rarely exceed 0.05 mm. in diameter.

Pleonaste is present in irregular grains, about 0.15 mm. in diameter, and is very dark green in colour; in fact, it is practically opaque excepting along very thin edges.

Nepheline, phlogopite, and sodalite are quite fresh and usually occur in rounded grains up to 0.25 mm. in size. The phlogopite is occasionally hypidiomorphic and then forms larger grains 1.0 to 2.0 mm. in diameter. These mica plates frequently include rounded grains of nepheline. The phlogopite is pale brown in colour and is slightly pleochroic.

One group of rounded grains was observed which resemble monticellite very closely. They are biaxial and negative, and polarize in first order greys and yellows, and have a moderately high index of refraction. The presence of monticellite would be quite in order in rocks so high in lime, and with such a low silica content as this one, although it may be stated that it was only found in the one section from this locality.

Chemical Analysis of Camptonite, Husereau Occurrence, Near St. Benoit
Analysis by W. V. Howard

SiO_2	27.81
Al_2O_3	7.59
Fe_2O_3	8.67
FeO	6.57
MgO	11.21
CaO	28.06
Na_2O	1.47
K_2O	1.26
H_2O-	0.11
H_2O+	1.24
TiO_2	1.33
MnO	0.08
P_2O_5	1.66
CO_2	2.51
	99.57

Spec. grav. 3.10

Norms

An	6.12
Ne	6.82
Kp	4.42
C	1.53
Ol	21.84
Cs	33.02
Mt	12.53
Il	2.40
Ap	4.03

CO_2 equivalent to 5.70% $CaCO_3$

Classification
Dofemane
Dopolic (Scotare)
Perolic
Calcimiric
Domagnesic
IV. 2. 5. 3. 2

As the principal rock type present in this locality is more basic than the other alnoites and associated rocks, and is associated with an acid nepheline rock, it would appear as if some differentiation had taken place before intrusion. This differentiation appears to have been somewhat similar to that at Mount Johnson where the basic differentiate is situated in the centre, and the more acid phases nearer the border. Here, however, the concentric arrangement so conspicuous at Mount Johnson is lacking and the more acid phases appear only as small intrusions around the border of the main mass. The contacts between the different phases is masked by drift.

Fourchite Sheet and Breccias at Ste. Dorothée

The southern part of the village of Ste. Dorothée (situated on Isle Jesus about 18 miles from Montreal) is strewn with boulders of a dark grey fine-grained igneous rock. This rock outcrops just east of the last house in the village along the St. Martin road, forming a small knoll 250 yards long from northwest to southeast, and 125 yards in width. It is best developed on the north side of the exposure where it was formerly quarried for road metal. Here the face is vertical, and the sheet is about fifteen feet in thickness. The outlier is in the form of a sill, and the underlying limestones and shales of the Calciferous formation are visible below the igneous rock at this point.

One hundred yards to the north is a small exposure of the same rocks, while about 200 yards to the north is another similar outcrop.

In the hand specimen, the rock is dark grey in colour, and small perfectly formed crystals of biotite, hornblende, and augite can readily be distinguished. These are embedded in a light grey feldspathic groundmass. On the south side of the exposure the dark rock is intruded by irregular dykes and stringers of a light brownish grey, feldspathic rock. The contact is usually quite abrupt, and the intruding rock is very irregular in outline, containing many inclusions of the darker type. Long needles of augite can be distinguished in the lighter intrusive, but the bulk of the rock seems to be feldspathic in character. This phase is well developed along the road, where a cutting has been made through the rock. The lighter rock is of the same nature as the groundmass of the normal rock, and appears to be a later injection which took place just before the original rock had completely cooled.

As this later injection shows most clearly the character of the groundmass, it is described in detail below.

The mineralogical composition of the two phases of the intrusive at Ste. Dorothée is as follows:

	Normal Type	Later Injection
Biotite	b	b
Hornblende	b	–
Barkevikite	b	b
Augite	a	–
Titanite	a	b
Iron Ore	c	–
Apatite	c	–
Labradorite	b	c
Analcite	b	a
Calcite	c	c
Heulandite	–	c (x)

a Abundant
b Subordinate
c Present
(x) Also present in irregular patches in the normal type.

Normal Type.—The normal type consists of phenocrysts of augite, hornblende, barkevikite, and biotite with accessory black iron ore, apatite, and titanite in a groundmass of labradorite and isotropic base. In places there are irregular patches bordered by aegirite-augite, and filled with labradorite, calcite, and an isotropic base.

Biotite occurs in deep brown idiomorphic individuals with a yellowish brown to very deep brown pleochroism. These attain a length of 0.5 mm. and are practically unaltered, although slight bleaching was observed in some individuals, and the ends of crystals cut perpendicular to the base are irregular, indicating partial resorption.

Common hornblende is present as perfect crystals up to 0.5 mm. in length. The mineral is yellowish brown in colour, and the pleochroism is very light yellowish brown, to brown.

Barkevikite also occurs as idiomorphic individuals up to 0.5 mm. in length. This was one of the first minerals to crystallize, and is partly enclosed by crystals of the lighter coloured hornblende. Its refractive indices are higher than those of the hornblende, and it is very dark in colour, closely resembling biotite both in colour and in shades of pleochroism. It is readily distinguished from the mica, however, by its crystal outlines. The cleavage in both minerals is greatly masked by the deep colour.

Augite is by far the most common ferro-magnesian constituent of the rock, and occurs both as large crystals up to 1.0 mm. in diameter and also as a host of smaller lath-like individuals usually about 0.1 by 0.3 mm. The mineral is the titanium-bearing variety and has a slight purplish tinge. It is slightly pleochroic, ranging from colourless to light purplish grey in colour. Some individuals have a tendency to irregular outlines indicating a slight amount of resorption.

Titanite is a very abundant constituent, almost equalling the ferro-magnesian minerals, with the exception of augite, in amount and occurs in regular rhombic crystals up to 0.3 mm. in length. It is practically colourless and non-pleochroic.

Black iron ore occurs as irregular grains, and consists of magnetite or ilmenite with small amounts of pyrite. Some of this iron ore appears to be secondary, and as some of the biotite and augite have been resorbed, the iron ore may have been derived from these minerals.

Apatite is present in minor amounts as minute laths.

The above minerals represent the phenocrysts in the principal variety; the irregular patches containing aegirite-augite, and the pegmatitic phase will be considered separately.

The groundmass consists principally of labradorite between $Ab_1 An_1$ and $Ab_2 An_3$, and an isotropic mineral.

Labradorite is almost universally twinned according to the Carlsbad law, but the albite twinning is less perfectly developed, and is lacking in the greater part of the feldspar present. The last stage in the solidification of the magma is marked by the formation of an amorphous colourless mineral. This isotropic mineral has a refractive index below that of Canada balsam, and it may be analcite or a glass of very low refractive index.

Calcite is present in the groundmass to a very small extent, but is more frequently associated with the irregular patches referred to above. While the groundmass is as a rule interstitial, there are some small patches, several millimetres in diameter, which are composed entirely of bytownite, calcite, and an isotropic base, in addition to aegirite-augite, and a zeolite (heulandite); these minerals do not appear elsewhere in the rock.

Two varieties of these patches are found in the normal phase of the intrusive. In the one case, there is a tendency to regular rounded outlines with small crystals of aegirite-augite around the borders, while the centres are filled with bytownite, heulandite, calcite, and the isotropic base. The other variety is simply an irregular jumble of microcrystalline augite, aegirite-augite, and calcite with an isotropic centre in which regular crystals of calcite 0.05 mm. in diameter occur. These aggregates are frequently surrounded by iron ore.

The augite occurring in these aggregates is similar to that in the main part of the rock except that the grains are rarely over 0.02 mm. in diameter.

Aegirite-augite is green in colour and is slightly pleochroic in grass green to bluish green shades. The crystals do not attain a diameter of more than 0.2 mm. and show a tendency to zoning. The mineral usually occurs as a border of intergrown crystals, often continuous about these patches. It does not occur elsewhere in the rock, and is not present to any extent in those patches where microcrystalline augite is present. The extinction angle is about 35°.

Heulandite occurs most frequently in those areas in which aegirite-augite is found, but is also present in small amounts in the areas filled with minute augite crystals. It forms small laths in the glass, and is colourless with a low birefringence and a refractive index only slightly higher than that of the base. It is biaxial and negative, and the cleavage is very indistinct.

The feldspar is more basic than the variety present in the main part of the rock, and is negative in character. It is considered to be bytownite about Ab_1 An_4.

Calcite is present in irregular grains, and although it is present in small amount in the rest of the rock, by far the greatest amount is associated with these included areas.

The isotropic base present in these patches is similar to that in the groundmass of the remainder of the rock.

The occurrence of these patches is possibly due to the segregation of part of the residual magma after the crystallization of the amphiboles, and biotite, and probably the greater part of the augite. This residue was rich in lime, alkalies, and silica, and probably contained a large part of the more volatile constituents of the magma such as water and carbon dioxide. Elsewhere the magma was not held in confinement and the normal sequence of crystallization was followed; labradorite followed the ferro-magnesian constituents, and was in turn succeeded by glass. In these areas which were in some way shut off from the rest of the magma, the order of crystallization was either of the normal type as in the places where microcrystalline augite occurs, or else some of the soda which otherwise would have entered the labradorite was included in the augite forming aegirite-augite, and the remainder of the magma crystallized as bytownite, heulandite, calcite, and the isotropic base.

Although these patches have been assumed above to be segregations within the magma, it is quite possible that they were injected into the rock along with the later intrusion. The contact between the two phases is sharp, and phenocrysts protruding from the rock into the later injection are quite fresh. In thin section, there appears to be a very narrow gradational phase along the contact, from which it may be deduced that this later magma was injected before the rock had entirely crystallized, in which case these patches might represent portions of the later rock which had found their way into the rock and had in some way displaced the unconsolidated magma and had crystallized in its place.

Arguments in favour of either viewpoint can be advanced. The fact that the minerals contained in the centre of these patches resemble very closely the minerals which make up the later intrusion and also the fact that these patches do not occur in sections cut at some distance from the injection, make it appear as if these areas were caused by the later intrusion.

On the other hand, it is difficult to see just how these small amounts of molten material were able to force their way into the earlier rock without affecting this rock at the contact more than they have done. The chemical composition of these patches is very nearly the same as that of the groundmass of the normal type and as the later injection is apparently of the same composition also, the mineralogical similarity of the patches and the pegmatite is not so significant as it appears at first.

The rock as a whole is thus composed essentially of augite, hornblende, barkevikite, and biotite in a groundmass of labradorite and glass, and can, therefore, be described as a fourchite.

Later Injection.—Although the contact between the normal type and the later intrusion is quite sharply defined in the hand specimen, in thin section it is marked only by an abrupt cessation of the ferromagnesian phenocrysts with a correspondingly marked increase in the more acid minerals which constitute the groundmass of the normal type. Basic constituents are by no means lacking in this phase, but they are subordinate to the groundmass. These constituents are titanite, barkevikite, and biotite, while the groundmass consists of labradorite, heulandite, and an isotropic base with some calcite which may or may not be secondary. Magnetite is also present.

Of the basic constituents, titanite and barkevikite occur in the same way as in the normal type, that is, in small idiomorphic crystals. These, however, are much smaller, usually being less than 0.05 mm. in length, and are not nearly so abundant as in the earlier intrusive.

Augite and hornblende are very rarely present, and their place is taken by long laths of biotite. Some of these laths are 1.0 mm. in length and only 0.03 mm. wide, but they are usually much smaller, the average size being less than 0.1 mm. by 0.01 mm. The biotite is deep brown in colour, and is strongly pleochroic in dark brown shades.

These basic minerals are more abundant near the contact than at a short distance away, although they are nowhere abundant in this phase. In fact, only a few millimetres from the contact they are confined to a few scattered grains.

The groundmass also varies in composition as it approaches the contact. Less than a centimetre away it is composed very largely of the isotropic, with the exception of a few irregular grains of calcite and laths of the feebly birefringent zeolite, heulandite. Frequently these laths have an isotropic centre symmetrical with the lath, and locally there are irregular areas a millimetre or so in diameter where heulandite and calcite occur practically to the exclusion of the base.

Labradorite occurs in very small amount, but the quantity increases towards the contact with the normal type where they form the greater part of the groundmass.

The groundmass of this later intrusion is thus very similar to that of the areas surrounded by aegirite-augite in the earlier rock and this probably represents an injection of the magma from below after the solidification of the greater part of the basic constituents of that magma.

Chemical Analysis of Fourchite, Ste. Dorothée
Analysis by W. V. Howard

SiO_2	44.43	Or	10.01
Al_2O_2	14.02	Ab	29.87
Fe_2O_3	4.86	An	14.46
FeO	6.09	Ne	2.84
MgO	4.08	Di	15.36
CaO	11.53	Ol	3.36
Na_2O	4.14	Mt	7.19
K_2O	1.73	Il	5.78
H_2O	1.96	Ap	2.02
TiO_2	3.03		
MnO	0.04	CO_2 equivalent to $CaCO_3$ 6.30%	
P_2O_5	0.83		
CO_2	2.77		
	99.53	(II) III. 5. (2)3. 4 ("3. 2. 2". 3)	

Classification
Salfemane
perfelic
alkalicalcic (camptonase)
dosodic (comptonose)

Spec. grav. 3.11

Breccias and Associated Dyke.—Half a mile to the northwest of this basaltic exposure, there are two knolls roughly elliptical in outline which are underlain in part by breccias similar in character to those at La Trappe and the other localities described by Harvie. These knolls are each about 150 yards long by 80 yards wide and the underlying rocks are generally masked by a blanket of drift. On the northern portions of these hills, there are several outcrops of breccia, and a smaller knoll similarly underlain lies about fifty yards to the northeast of the southern hill and along the strike of the outcrops of breccia on the latter knoll.

The included fragments are mainly of limestone, but as no fossils were found, no definite information as to the age of these inclusions can be given. Fragments of Laurentian granites and gneisses are also present and must have been brought up from a considerable depth, as the surrounding country is underlain by the Calciferous formation. In this connection, it is noteworthy that the breccias at La Trappe cut the Laurentian and contain fragments of the Potsdam sandstone and Calciferous limestone, and, therefore, there must have been a great deal of movement within the magma in both directions before final solidification.

The paste of the northern breccia has been almost entirely altered to calcite and secondary quartz, and very little can be determined concerning its original composition. Fragments of feldspars of very different composition are present. These include $Ab_1 An_3$, $Ab_3 An_4$, and $Ab_4 An_3$. Most of these are probably fragments of included igneous rocks and not constituents of the magma itself.

In the paste of the southern breccia there are feldspar grains ranging from albite to labradorite so that it is impossible to state which are constituents of the magma and which are inclusions. The paste is very highly altered to calcite and secondary quartz, while grains of black iron ore and very irregular flakes of a light-brown biotite are also present. These flakes resemble the biotite of the alnoitic occurrences much more closely than the neighbouring fourchite exposure of Ste. Dorothée.

On the west side of the road from Ste. Dorothée to St. Eustache, about two miles from the former village, there is a quarry in the Calciferous limestone. This limestone is here traversed by a highly altered dyke about one foot in width. The only mineral which is distinguishable in the hand specimen is calcite, as the rock as a whole has been obscured by hydrous iron oxides.

The minerals of which this dyke was originally composed cannot be distinguished by means of the microscope, as it has been rendered almost opaque even in thin section by the hydrous iron ore. The only minerals which could be identified are calcite, quartz, and an indefinite feldspathic mineral. This dyke is of no importance except that it is undoubtedly associated with the breccias which lie about one-half mile to the east.

These breccias do not appear to be genetically connected with the fourchite sill. The only evidence in favour of this connection consists of the proximity of these breccias to the sheet.

On the other hand, this fourchite is not in any way similar to any of the other exposures described in this paper, and the breccias at La Trappe as well as all those described by Harvie are closely related to alnoitic rocks. The biotite present in the paste of one of the Ste. Dorothée breccias resembles the biotite of the alnoites rather than the deep brown variety at Ste. Dorothée. It is also noteworthy that the rocks connected with the breccias elsewhere are very much altered while those at Ste. Dorothée are quite fresh. It is, therefore, supposed that these breccias like those at the White Horse Rapids four miles to the south and those at La Trappe are associated with a much more basic rock than the fourchite at Ste. Dorothée, although this rock has not yet been discovered in this locality.

Relationships of the Alnoitic and Associated Rocks

The normal types of the basic intrusives described above, with the exception of the basalt at Ste. Dorothée, are very closely related to one another. To these may be added the various localities described by Harvie in which breccias occur associated with alnoitic dykes and also the monticellite alnoite at Isle Cadieux, described by Bowen, and the alnoite at Ste. Anne de Bellevue, described by F. D. Adams. All of these are of somewhat different mineralogical composition, as may be seen by the following table:

Essential Constituents of Alnoites and Associated Rocks of Western Quebec

	Ste. Anne de Bellevue	Isle Cadieux	Como	Ste. Monique	La Trappe	Husereau
Mica	x	x	x	x	x	x
Olivine	x	x	x	x	x	x
Pyroxene	x	x	x	x	x	x
Melilite	x	x	x	–	–	–
Nepheline	x	–	–	–	–	x
Perovskite	x	x	x	x	x	–
Labradorite	–	–	–	–	x	–
Andesine	–	–	–	–	–	x

The ferro-magnesian constituents have been classed as groups rather than minerals but there are minor variations in each of these constituents. The mica is biotite; the olivines are chrysolite and monticellite; and the pyroxenes are augite, titaniferous-augite, and diopside.

Perovskite is almost a universal constituent, while the groundmass may contain melilite, nepheline, labradorite, or andesine.

That these rocks are really very closely related can be seen by a glance at the following table of chemical analysis and the accompanying norms:

Analysis of Alnoites and Associated Rocks

	I	II	III	IV	VI	VII	VIII	IX	X
SiO_2	30.27	31.63	30.78	27.81	33.26	30.85	31.10	35.91	29.24
Al_2O_3	10.00	10.60	1.49	7.59	5.90	8.21	10.08	11.51	11.40
Fe_2O_3	4.88	4.56	5.64	8.67	5.30	3.33	3.64	2.35	5.84
FeO	6.95	6.42	10.34	6.57	6.54	6.52	3.35	5.38	4.74
MgO	20.11	17.82	16.35	11.21	26.41	23.16	12.25	17.54	10.38
CaO	14.73	17.16	22.02	28.06	14.47	16.46	22.77	13.59	18.35
Na_2O	1.49	0.61	2.85	1.47	1.23	1.01	1.95	1.75	1.44
K_2O	2.85	2.48	0.67	1.26	0.82	1.43	3.56	2.87	2.42
H_2O+	2.17	0.93	0.98	1.24	1.91	1.22	0.76		5.05
H_2O-	..	..	..	0.11	0.09	0.05	0.46	9.40	1.04
CO_2	3.24	4.92	2.78	2.51	1.10	3.04	4.94	..	5.02
TiO_2	2.84	2.44	3.33	1.33	2.15	2.87	2.73	0.23	2.40
P_2O_5	0.95	1.09	2.07	1.66	0.76	1.90	2.01	..	2.10
MnO	0.16	0.11	0.10	0.08	0.15	0.21	0.09	..	0.19
XO	..	..	..	..	0.35	..	..	..	0.57
	100.64	100.77	99.40	99.57	100.44	100.26	99.69	100.51	100.45

XO in VI $= Cr_2O_3$ 0.05 BaO 0.08 SO_3 0.22 in X BaO 0.24 SO_3 0.33

Norms

	I	II	III	IV	VI	VII	VIII	IX	X
An	8.06	18.63	..	6.12	8.06*a*	10.01	8.06	15.01	20.29
Le	..	6.54	3.05	..	..	..	13.08	13.52	11.34
Kp	9.80	3.79	..	4.42	1.93	4.74	2.53	..	..
Ne	6.82	2.84	2.27	6.82	5.68	4.54	9.09	7.95	6.53
C	1.43	..	Ac6.93	C1.53	..	1.33	..	..	..
	..		Ns2.81					Di4.90	2.81
Ol	36.57	34.38	36.98	21.84	49.56	44.20	21.42	34.97	17.22
Cs	11.77	8.67	23.99	33.02	15.82	12.56	18.40	4.99	6.71
Mt	7.19	6.73	4.64	12.53	7.66	4.87	3.25	3.48	8.35
Hm	..	..	..	..	..	..	1.44	..	..
Il	5.32	4.56	6.38	2.40	4.10	5.47	5.17	0.30	4.56
Ap	2.35	2.69	5.04	4.03	2.02	4.37	4.70	..	5.04
Cc	7.40	11.10	6.30	5.70	2.50	6.90	11.20	10.70	11.40

		Analyst	Symbol
I.	Monticellite alnoite, Como	W. V. Howard	IV. 2. 5. 2. 2
II.	Monchiquite, Ste. Monique	W. V. Howard	IV. 2. 5. 3. 2
III.	Biotite-Peridotite, La Trappe	E. P. Dolan	V. (1) 2. 4(5). (2) 3. 2
IV.	Camptonite, Husereau	W. V. Howard	(III) IV. 2. 5. 2. 2
VI.	Monticellite alnoite (melilite—rich), Isle Cadieux	H. S. Washington	IV. (1) 2. 5. 2. 1
VII.	Monticellite alnoite (melilite—poor), Isle Cadieux	H. S. Washington	IV. (1) 2. 5. 2. (1) 2
VIII.	Melilite-biotite rock, Isle Cadieux	H. S. Washington	III(IV). 6. 2. 3
IX.	Alnoite, Ste. Anne de Bellevue	P. H. LeRossignol	III. 7. 3. 3 1''. 5. (1) 2. (1) 2
X.	Alnoite Point St. Charles	M. F. Connor	III. 7. 3. 3 2'' .(4) 5. 2. 2

a Norm calculated by H. S. Washington. All others by W. V. Howard. In IX it was assumed that $CO_2=\frac{1}{2}$ (H_2O+CO_2) This norm would probably be much altered had CO_2 and P_2O_5 been determined. SiO_2 is high and TiO_2 low.

These basic rocks, therefore, may be classified as follows:

III. 6. 2. 3. (2. 5. 3. 2)
Melilite-biotite rock, Isle Cadieux
III. 7. 3. 3. (1 or 2. 5. 2. 2)
Alnoite, Ste. Anne de Bellevue
Alnoite, Point St. Charles
IV. 2. 5. 2. 1
Monticellite alnoite (melilite—rich), Isle Cadieux
IV. 2. 5. 2. 2
Monticellite alnoite, Como
Camptonite, Husereau
Monticellite alnoite (melilite—poor), Isle Cadieux
IV. 2. 5. 3. 2
Monchiquite, Ste. Monique
V. 2. 4. 3. 2
Biotite-Peridotite, La Trappe

Thus there is no doubt but that they are genetically related. As the relationship between alnoitic rocks and the breccias has been pointed out by Harvie, it seems logical to consider them to be roughly contemporaneous.

Harvie points out in his paper (page 260) that the breccia on the southwest end of Isle Bizard contains fragments of pyroxenites and hornblende rocks and (page 269) that the breccia on Westmount Mountain contains essexite and a pyroxene-hornblende rock. These essexites and pyroxene hornblende rocks represent the earlier intrusive at Mount Royal, namely, the essexite. The breccias and probably the associated alnoites are, therefore, later than the essexite, and may represent a basic differentiation of the main magma of which the nepheline syenite of Mount Royal is the counterpart.

The only analysis requiring special consideration is that of the biotite-peridotite at La Trappe. It has been shown above that during the formation of the breccias in this locality, the basic constituents of the dykes settled toward the main intrusive. Apparently this differentiation went on to some extent in the main intrusive itself and we see by the norm that the rock is very deficient in salic minerals. An increase of less than 10 per cent (an amount approximately equal to the proportion of normative acmite and sodium metasilicate) would bring this rock into the same position as that occupied by the monchiquite from Ste. Monique. That the analysis is faulty as regards the alumina is doubtful, as the summation is close to 100 and the magnesia is not high.

On the other hand, this differentiation after intrusion may not have taken place, and the magma may simply have been deficient in alumina. In any case there can be no doubt that this rock is closely associated with the other alnoitic and basic rocks described in this paper.

Relationships of the Ste. Dorothée Fourchite and Breccias

The fourchite sheet at Ste. Dorothée, on the other hand, appears to be very similar in composition to the essexites of the Monteregian Hills. Hornblende, augite, and biotite are always present in these rocks and barkevikite is a common constituent. These minerals form essential constituents at Ste. Dorothée.

Chemically the fourchite at Ste. Dorothée resembles the essexite of Mount Royal very closely, although it is intermediate between this rock and the essexite of Mount Johnson in the classification. The essexites of Mount Royal and Mount Johnson, the pyroxenite of St. Bruno, and the basaltic vitrophyre from Ste. Dorothée may be classified as follows:

II. 5. 3. 4.
Essexite, Mount Johnson
III. 5. 3. 4. (3. 2. 2. 3)
Fourchite, Ste. Dorothée
III. 6. 3. 4. (2. 2. 3. 2)
Essexite, Mount Royal
IV. 1. 2. 2. 2
Olivine pyroxenite, St. Bruno
IV. 3. 3. 2. 3.
Olivine Essexite, Mount Royal

Analyses of the Fourchite at Ste. Dorothée and the Essexites of the Neighbouring Monteregian Hills

	XI	XII	XIII	XIV	V
SiO_2	48.85	43.10	44.66	45.37	44.43
Al_2O_3	19.38	13.94	9.64	6.21	14.02
Fe_2O_3	4.29	4.92	4.98	2.40	4.86
FeO	4.94	6.93	6.65	8.09	6.09
MgO	2.00	8.86	12.83	18.67	4.08
CaO	7.98	14.65	13.11	14.47	11.53
Na_2O	5.44	2.50	2.07	0.85	4.14
N_2O	1.91	0.89	1.17	0.37	1.73
H_2O+	0.68	0.55	0.79	0.88	1.96
H_2O-	..	0.15	0.11	..	..
TiO_2	2.47	2.80	2.27	1.50	3.03
P_2O_5	1.23	0.27	0.24	..	0.83
MnO	0.19	0.14	0.19	0.15	0.04
CO_2	..	0.64	0.37	0.62	2.77
XO	..	0.28	0.32	..	..
	99.36	100.62	99.40	99.75	99.51

Norms

Or	11.12	5.56	7.23	2.22	10.01
Ab	36.41	5.76	8.64	2.62	29.87
An	22.80	23.91	13.34	11.95	14.46
Ne	4.97	8.24	4.97	2.56	2.84
Di	6.92	33.84	37.52	47.68	15.36
Ol	2.43	8.18	13.70	25.01	3.36
Mt	6.26	6.96	7.19	3.48	7.19
Il	4.71	5.32	4.20	2.89	5.78
Hm	..	..	..	..	..
Ap	3.02	0.67	0.67	..	2.02
Cc	..	1.50	..	..	6.30

XI Essexite, Mount Johnson, by N. N. Evans, II. 5. 3. 4
XII Essexite, Mount Royal, M. F. Connor, III. 6. (3) 4. 4. 2. 2. ″3. 2
XIII Olivine Essexite, Mount Royal, M. F. Connor, (III) IV. 2. 2. 2. 2
XIV Olivine Pyroxenite, St. Bruno, M. F. Connor, IV.1″.2 (3). 2.2
V Fourchite, Ste. Dorothée, W. V. Howard (II) III. 5. (2)3. 4. ″3. 2. 2″ .3

Thus the Ste. Dorothée intrusive is, in all probability, contemporaneous with the earlier intrusives of the Monteregian Hills, and, therefore, earlier than the more basic alnoitic intrusions which surround it.

Summary and Conclusions

This paper consists largely of a petrographical description of five igneous intrusions which lie to the west of Montreal, and which are undoubtedly outliers of the Monteregian Petrographical Province. Four of these intrusions consist of alnoites or of very similar basic rocks and are situated at Como, Ste. Monique, La Trappe, and on the Husereau Farm near St. Benoit, all in the Province of Quebec. The fifth is a fourchite sheet from Ste. Dorothée on Isle Jesus. Two breccias are also briefly described, one from La Trappe and the other from near Ste. Dorothée.

These intrusives are all very closely related to one another, with the exception of the fourchite from Ste. Dorothée. This sheet-like intrusion is considered to be contemporaneous with the essexites of the western Monteregians of which it is the hypabyssal equivalent.

The breccias occurring to the north of Ste. Dorothée are in all probability related to the breccias described by Harvie rather than to the fourchite which occurs in the immediate vicinity, and, therefore, were formed later than the latter.

The more basic intrusions together with the alnoites described by Bowen from Isle Cadieux, and by F. D. Adams from Ste. Anne de Bellevue, form a line roughly bordering the intrusive breccias toward the west. The alnoitic intrusives are closely associated with the breccias described by Harvie. The intrusive at La Trappe is undoubtedly connected with breccias nearby, and the alnoite dyke at Ste. Anne de Bellevue may be associated with the neighbouring breccia.

All of the alnoitic rocks apparently commenced to crystallize out as monchiquites (that is, as olivine-augite-biotite rocks), but some change in conditions of crystallization caused the partial resorption of the earlier minerals and new minerals were formed; because of different conditions prevailing in each locality, the later minerals are not the same in each of the various occurrences. Each occurrence is itself composed of several phases which may be products of magmatic differentiation before intrusion as at the Husereau occurrence, or after intrusion as at La Trappe, or they may be simply textural variations of the principal type as at the other localities.

Most of the rocks encountered and also some of the phases of each occurrence show associations of minerals for which names have not been provided in the Qualitative Classification. Following Bowen's example, the writer has decided not to add any new names to a nomenclature already overcrowded with names based on locality rather than on the mineralogical composition of the rocks occurring at that locality.

Although these basic rocks differ slightly in their mineralogical composition, they are not only related to one another and to the breccias, but they also represent basic differentiation products of the normal essexite of which the nepheline syenite of Mount Royal represents the acid differentiate. Fragments of essexites but none of nepheline syenite have been reported in the breccias, so that they and the basic intrusives with which they are closely related are later than the essexite and probably earlier than or contemporaneous with the nepheline syenites.

An interesting feature of these occurrences is the presence of monticellite. This mineral was first recognized by Bowen in the alnoite at Isle Cadieux although he also found it in an alnoite from the original locality of Alno.

This mineral was also found in rocks from Como, Ste. Monique, and possibly in the Husereau occurrence. Bowen states that "......it seems not unlikely that the monticellite may be of reasonably frequent occurrence in alkalic rocks," and points out that pure lime olivine (Ca_2SiO_4) has been found in such rocks. Although the norms as calculated in the Quantitative Classification of igneous rocks are not intended to represent the actual minerals present in the rock, still it seems reasonable to expect that in rocks whose norms contain calcium orthosilicate, there must be a mineral of very nearly the same composition in the rock itself. Otherwise it is extremely difficult, if not impossible, to account for the high lime content and low silica content of such rocks.

The first intrusion of alkalic rocks in the western part of the Monteregian Hills is represented by the essexite of Mount Royal. This essexite was followed by differentiation products, the more acid differentiate forming an intrusion of nepheline syenite at Mount Royal, while one of the more basic products was intruded as a number of basic alnoitic rocks lying to the west of Montreal with associated dykes and sheets of breccia. These basic rocks are remarkably low in silica and contain the lime orthosilicate monticellite which has hitherto been regarded as of very rare occurrence as a primary constituent of igneous rocks.

The Historical and Structural Geology of the Southernmost Rocky Mountains of Canada[1]

By J. D. MACKENZIE, PH.D.

Presented by W. H. COLLINS, B.A., PH.D., F.R.S.C.

(Read May Meeting, 1922)

INTRODUCTION

The Rocky mountains of Canada south of the Crowsnest pass are a region of much geologic importance. Not only do they contain coal deposits of great magnitude, but the geologic structures exposed present features of much significance. The amount of information at present available on the geology of this region is not large. In a few restricted areas within it, detailed work has been done; in other portions reconnaissances have been made; but much of it has yet to echo to the geologist's hammer. My own introduction to the region was in 1912 when I spent three delightful months studying the coal-bearing area drained by some of the southern tributaries of the Oldman river in southwest Alberta, for the Geological Survey, Canada. In the same year a short reconnaissance was made into the Flathead valley in the company of Dr. D. B. Dowling. In 1914 a short time was spent in examining a small area in the lower Flathead valley, well within the mountains themselves.

Many of the structural relations observed in this region were so puzzling that an explanation of their origin was not attempted in my reports on the localities studied. After consideration of the available evidence, an hypothesis serving to explain how the observed structures may have arisen has been formulated and that hypothesis is elaborated in this paper. There are too many facts still to be learned to hope that those in hand furnish a complete explanation. However, enough is known to venture a preliminary one, which I think at least contains the germ of the truth.

Several of the men who have worked in this region have afforded me the advantage of discussion by correspondence or otherwise, and I wish to acknowledge my indebtedness in this respect to Messrs. D. B. Dowling, F. H. McLearn, J. R. Marshall, Bruce Rose, S. J. Schofield, and Bailey Willis.

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The general problem for which a solution is advanced in this paper is the origin of the present structures of the Rocky mountains of Canada south of the Crowsnest pass. A particular part of this problem is the origin of the parallel steep reverse strike faults of the foothill region in Alberta. It was in seeking an explanation for the attitude of these faults that my attention was directed to the more general problem as stated above.

Summary

The southernmost Rocky mountains of Canada are composed of a succession of virtually parallel sedimentary rock formations belonging to the Precambrian, the Palæozoic, and the Mesozoic eras. The rocks of each of these eras form units that are separated from each other by breaks which are essentially disconformities, though in some places they may be unconformities. From the earliest Precambrian known until at least the beginning of the Tertiary the accumulation of sediments proceeded, without interruption by pronounced deformation, varied from time to time by broad and relatively slight oscillations which caused local erosion and resulted in the disconformities mentioned above. After the deposition of the Fort Union formation, the age of which is either late Cretaceous or early Tertiary, this great mass of strata, 40,000 feet thick, was severely deformed by a thrust acting from the west. This thrust was one of the consequences of the Laramide revolution. These compressive stresses folded, faulted, and overthrust the strata, and the effect of the compression and the relaxation following it has been to leave the rocks in the positions they now occupy.

The significant structural elements of the region may be described in terms of three areas elongated parallel to the mountains. These are: (1) a western area, with structures characteristic of tension following compression; (2) a central area with structures characteristic of severe compression, the eastern boundary of which is the great Lewis overthrust; and (3) an eastern area, the cause of the structures of which is not at once apparent. The very steep reverse strike faults of this area are explained as being due to a rotation of slices of the earth's crust above flat overthrusts or "soles" in a manner analogous to the formation of the more complex but generally similar structures of the Scottish highlands.

Willis explained the Lewis overthrust as being an erosion thrust consequent on early Tertiary peneplanation following an earlier episode of compression and followed by a later episode, when renewed compression drove the western limb of an anticline over folded territory to the east. This hypothesis is considered in some detail, and the reasons for dissenting from it are given. An hypothesis based on a single episode of compression is presented, which considers the Lewis overthrust and the steep reverse faults of the Mesozoic rocks of the foothills to have developed in connection with "soles" of the Scottish type. Relaxation following this single episode of compression completed the present structures of the mountains.

Historical Geology

The earliest events in the history of this part of the Rocky mountains are recorded in a great mass of sediments divided by Daly into the Lewis and the Galton series (12,a) which Schofield has stated to be wholly of Precambrian age (36). These rocks are of various characteristics, and the section of the Lewis series given by Daly (12, b) will serve to give an idea of their composition.

Formation.	Thickness in feet.	Dominant rocks.
	Top erosion surface.	
Kintla	860*	Argillite
Sheppard	600	Siliceous dolomite
Purcell lava	260	Altered basalt
Siyeh	4100	Magnesian limestone and metargillite
Grinnell	1600	Metargillite
Appekunny	2600	Metargillite
Altyn	3500	Siliceous dolomite
Waterton	200*	Siliceous dolomite
	13,700	

*Base concealed.

Diverse opinions are held as to the origin of this series by those who have worked on it. The Kintla, Grinnell, and probably the Appekunny are certainly of continental origin as shown by their unmistakable characteristics. The dolomites are stated by Daly (12,c) to be chemical precipitates in marine basins, while Walcott suggests that they are of epicontinental origin and precipitated in fresh water through the agency of algae (43, a). Whatever its origin this Precambrian sedimentary series forms a unit, though opinions differ as to how distinct it is from the succeeding Palæozoic series. Thus Walcott considered them to be separated by a lengthy period of uplift and erosion (43,b), while Daly states the view that these two series form "a simple Palæozoic-Beltian geosynclinal prism, which is only locally interrupted by unconformities" (12,d). Evidence that there was an interval of erosion between the Precambrian and the Palæozoic is given by Schofield. At Elko, British Columbia, he found the lowest middle Cambrian Burton formation lying without angular discordance on rocks which he assigns to the Precambrian (36,a), (5,a). Further evidence of a break in sedimentation is given from the North Kootenay pass by Adams and Dick (1,a); and Rose also recognizes a disconformity at the base of the Palæozoic. In the summer of 1921 Schofield discovered a conglomerate at the base of the Cambrian containing *Olenellus* and resting on Beltian rocks (55).

The Palæozoic era in this region was a time of marine sedimentation resulting in the accumulation of fossiliferous limestones, shales, and sandstones. While sedimentation was general during this era it was not continuous, and disconformities have been recognized even in the comparatively few sections studied (36,b), (6,a), (32,a). Rocks representative of the time from the lower Pennsylvanian to the lower Jurassic are absent in the region, except possibly for a formation to be described presently. This break in the record is interpreted as meaning that near the close of the Palæozoic era the Rocky Mountain geosynclinal was broadly uplifted without appreciable deformation. In the region under consideration the uplift was later than the lower Pennsylvanian, as indicated by the fossils found in the Flathead valley (26,a), and tentatively it may be assigned to the Permian. It is at any rate of a later date than that assigned to it by Daly, whose fossil record did not carry him beyond the upper Mississippian (12,c). It is supposed that from the beginning of the Permian to the lower Jurassic this region was land—a terrane of low relief, mainly of limestones, but with some sandstones—undergoing subaerial weathering with probably but little loss of the products of rock disintegration. The rock record for this stretch of time is here a blank, with but one known exception as noted above, but is at least partly represented in the region near Banff, Alberta (39,a). The exception is a white sandstone formation, which, on inconclusive evidence, has been assigned to the Triassic (26,b). This formation has been interpreted as the result of the disintegration and reconcentration of quartz sandstones, so it may be supposed that the sandstone interbeds of the limestone terrane were exposed as ledges, disintegrated, and their constituents accumulated and re-sorted both by wind and streams and perhaps local lakes, for the sandstone possesses properties of both aeolian and aqueous deposits.

The third era of sedimentation, the Mesozoic, was initiated by a subsidence previous to the lower Jurassic, and which may have taken place in the upper Triassic. In the early stages of this subsidence, it is supposed that part of the sandy mantle of the land was concentrated to form the quartzose sandstone which has been assigned to the Triassic. Following this, by reason of increased subsidence, marine waters gained access to the region, in the form of a sea trending north-northwest and south-southeast, and extending at least as far south as, and probably beyond the 49th parallel. From the varying thicknesses and uniform character of the sediments formed (the Fernie formation) it is apparent that great volumes of fine mud were delivered to this sea by rivers flowing from low land to the west, and there may have been several large estuaries along the western edge of the marine basin of that time. The sea was probably never very deep, judging from the occurrence of the reptilian remains which have been found in three localities (2,a), one of which is within the area under consideration (17,a), (24,a). The combination and attitude of the bones at this place indicate only a small amount of transportation. A thin bed of a greenish rock which McLearn has termed tuff (27,a) occurs in the Fernie formation. If its designation as tuff be correct, it marks the first evidence of igneous action in the Rocky Mountain area since the Precambrian Purcell lavas. It was in this bed that the reptilian bones were found in 1912.

The Fernie is transitional into the overlying Kootenay formation (24,a), (27,b) and there is apparently no cessation of deposition recorded, yet the marine waters must have gradually withdrawn, and widespread freshwater lake basins must have succeeded them. In these shallow lakes the Kootenay measures were laid down.

The conditions of Kootenay time may be interpreted from the nature of the sediments. Westward from the present Kootenay river stretched an undulating land, of moderate relief, extending hundreds of miles to the north-northwestward, and drained by many eastward flowing streams of moderate gradient. This land was being uplifted. The bedrock of the terrane in the eastern portion of this region was limestone, probably Pennsylvanian in age, and was mantled with residual chert in fragments of varying size. Farther west the quartzites and argillites of the lower Palæozoic and the Precambrian were exposed, but there is no evidence of plutonic rocks occurring at the surface in this westward land at this time. Eastward as far as the present edge of the great plains, and parallel to this land, extended a low, marshy plain, its surface covered with shallow lakes, which slowly but continually shifted their positions, aided by periodic risings of the rivers over this area, which was in effect the coalescent flood-plain of many streams. Into these lakes through the agency of the rivers were carried muds and sands, the latter composed almost wholly of the finer chert fragments from the residual mantle of the adjacent Palæozoic limestones to the west. Vegetation was abundant and luxurious, and at several recurrent intervals thick masses of virtually pure vegetable matter were accumulated which to-day form coal seams. As the lakes shifted, shifting some of this vegetable matter with them, it was covered with cherty sands, which form the characteristic Kootenay sandstones of to-day. During this stage of freshwater sedimentation continual sinking took place, and the region was bent down into a trough whose eastern edge is defined by the eastern feather-edge of the Kootenay formation of the present, which is probably not far east of the western edge of the great plains. The western edge of the trough can not be defined at present; the Kootenay river may be set as its boundary.

The western exposures of the present day Kootenay strata are notably coarser than those occurring farther east, especially in the upper portion of the formation (22,a), (32,b), so it is apparent that the westward land from which the debris came was rising, and its streams gaining in power (26,b), (37,a). Finally an accelerated uplift raised the westward land relatively higher, drained the eastward region of its lakes, and closed the Kootenay stage. The rejuvenated streams spread over the newly exposed soft lake sediments, and removed a portion of them, covering the remainder with a veneer of cherty and quartzitic pebbles, the last remaining coarser residual chert and quartzitic debris of the land to the west. This gravel was spread evenly over an enormous extent of territory and is now found overlying the Kootenay formation throughout the southern Rocky mountains (8,b), (18,a), (24,a), (27,b), (32,b), (41,a).

Following this erosion and deposition of conglomerate, renewed subsidence again caused freshwater lake basins to form, but the lakes were smaller, shallower, and less persistent than those of Kootenay time, for the sediments are distinctly more lenticular, less sorted, and contain red beds. For these reasons the massive green sandstones of the Blairmore formation of southwest Alberta are unreliable as horizon markers. These sandstones carry plant remains and freshwater molluscs in thin limestone bands (24,b), (27,b) and have been given the name Blairmore formation by Leach (19,a), (41,b). The upper Blairmore formation contains claret coloured shales and sandstones and these with their ripple-marks and mudcracks indicate terrestrial sedimentation.

A thin bed of tuff in the Blairmore (18,b) is the result of slight volcanic action, which culminated in the Crowsnest volcanic episode, when explosive eruptions of a highly specialized alkaline magma took place in a relatively localized area in the vicinity of the Crowsnest pass, forming one of the very few manifestations of igneous activity in the Rocky mountains of Canada (25). Immediately after this volcanism a subsidence and a marine invasion took place, forming shales which are called the Benton formation, but which may be subdivided on more detailed study. The quiet marine conditions of the Benton were followed by shallow and in part freshwater conditions during which the coarse, crossbedded rocks of the Belly River formation were formed. Succeeding the Belly River stage a marine invasion occurred during which the shales of the Bearpaw formation were laid down, and this was followed by a stage in which conditions similar to those of the Belly River recurred, during which the rocks of the St. Mary River formation were accumulated, these being the latest rocks of the Mesozoic era in this region (41,c)

The rocks accumulated in the third consecutive era of sedimentation, the Mesozoic, are thus seen to be altogether of shallow water, and largely of freshwater origin, though three marine stages are represented. In this era there was at least one widespread interval of slight erosion, and there was also some local volcanism of relatively small significance from a rock-forming point of view. The historical interpretation of the stratigraphic facts as stated in this paper is at variance with Willis' hypothesis (45,a) of a Mesozoic peneplain, and corroborates Daly's view that "It would seem probable that during the Mesozoic, this part of the Cordillera was never far above sea-level (12,f). From the earliest Precambrian known in these Rocky mountains to the Upper Cretaceous or early Tertiary, a stretch of time representing most of the recorded geologic history of the globe, there is no evidence in this region for more than relatively slight uplifts and depressions, with no more deformation than that consequent on differential subsidence. After the Upper Cretaceous or early Tertiary (Fort Union) sedimentation had piled its load on the tremendous mass of sensibly parallel strata underneath, a vast and relatively rapid deformation affected the region, which is known as the Laramide revolution. The effects of this revolution are now visible in the severely folded and faulted sediments of the Rocky Mountain geosynclinal, from the oldest known, the Waterton dolomite, to the youngest, the Porcupine Hills formation.

Different interpretations have been given with respect to the date of the Laramide revolution in this region. Willis considers it to have taken place as two episodes of compression, the earlier "not earlier than Laramie time nor later than early Tertiary" (45,b) and a later one in the mid-Tertiary (45,c). Daly takes the view that the post-Cretaceous movements all belonged to a single orogenic episode (12,g) before "the dawn of the Tertiary" (46,a).

Evidence that has a direct bearing on the date of the Laramide revolution is available from two widely separated localities. The first locality is in the Cypress hills, which rise above the general surface of the Great Plains in southwestern Saskatchewan. The other locality is in the Flathead valley, well within the Rocky mountains themselves. The evidence from the Cypress hills is the more conclusive, though the Flathead evidence, which is not so convincing, nevertheless is corroborative of the other. Taken together, they afford fairly satisfactory data as to the latest date at which the Laramide revolution could have taken place.

The Cypress hills are 200 miles from the present front ranges of the Rocky mountains. They were studied by McConnell in 1883 and 1884. McConnell states (52,a) that the reason for the present elevation of the Cypress hills is because of a sheet of resistant conglomerate which caps them, and has preserved them as an erosion remnant surmounting the adjacent Great Plains to a height of 2,000 feet. Vertebrate fossils from this conglomerate were studied by Cope, who gives their age as Oligocene (53). This Oligocene conglomerate is usually composed of quartzite pebbles up to nine inches in diameter, though the usual size is two to four inches. The quartzites are usually white on a fresh fracture, but grey and flesh coloured tints are common (52,b). These pebbles are derived from the quartzite formations of the Rocky mountains (52,a) which, as already stated, are 200 miles to the westward.

The conglomerate[1] rests unconformably on the subjacent strata, the highest of which are stated by McConnell to be Laramie. These Laramie strata are predominantly fine grained, contain coal, and are evidently of freshwater origin (52,c). They are correlated with strata of the Willow Creek and Porcupine Hills (Fort Union) stages of Southwest Alberta (41,g). It is apparent that to carry pebbles of the size and in the quantity described for a distance of 200 miles from their source a powerful current is required, which necessitates, as McConnell points out, a gradient of at least 15 feet per mile (52,a).

The interpretation of the evidence afforded by this conglomerate is that immediately preceding its deposition the mountain region underwent a rapid and pronounced uplift. This uplift is considered

[1]McConnell described it as Miocene but the later determination of the fossils by Cope gives the age as Oligocene.

to have been that of the Laramide revolution. The latest date, therefore, at which this revolution could have occurred is late Eocene, or possibly early Oligocene.

The evidence on the date of the Laramide revolution from the Flathead valley is as follows:—

The front range of the Rocky mountains north of the boundary, the Clarke range, is bounded on the west by the Flathead valley, the east wall of which is marked by a profound normal fault (12,b), 45,d). This normal fault is later than the compressive stresses of the Laramide revolution, for, as Willis has pointed out, the normal fault has detached the Clarke range so that the strata could not in their present position have received the pressure which overthrust and flexed them (45,d). The fault probably took place during the relaxation immediately following the compression of the Laramide revolution (26,c).

The age of the normal faulting is dependent on the age of the Kishenena formation, which was laid down in the Flathead valley in lake basins consequent on the faulting, and is, therefore, younger than the beginning of the faulting (26,c). The evidence for the age of the Kishenena formation is derived from fossils it contains, some of which, collected by myself in 1914, were determined by Dr. W. H. Dall, who reports finding (26,d) "two species of 'Planorbis,' crushed flat...and the remains of a species of 'Physa.' The shells are specifically indeterminable owing to their bad state of preservation, but the larger one recalls '*Planorbis utahensis*' White, and the smaller multispiral one '*Planorbis cirratus*' White, the former from the Bridger group, and the latter from the Green River beds of Wyoming. Only a guess is permissible, yet a probability of Eocene is existent so far as I dare express an opinion." Fossils collected by Daly were examined by Dr. T. W. Stanton, who reported the collection to consist entirely of freshwater shells belonging to the genera Sphaerium, Valvata (?), Physa, Planorbis, and Limnaea. Similar forms occur as early as Fort Union, now regarded as earliest Eocene, but there is nothing in the fossils themselves to prevent their reference to a much later horizon in the Tertiary, because they all belong to modern types that have persisted to the present day, though it should be stated that their nearest known relatives among the western fossil species are in the Eocene. Doctor Stanton lists the species as follows:—

Sphaerium sp., related to *Sphaerium subellipticum* M. and H.
Valvata (?) sp., resembles *Valvata subumbilicata* M. and H.
Physa sp.
Planorbis sp., related to *Planorbis convolutus* M. and H.
Limnaea sp.

The best that can be said for this evidence is that it indicates that the Kishenena formation is probably of Eocene age, and to that extent it indicates that the Laramide revolution is probably not later than Eocene in date.

Stewart has shown that the Laramide revolution has deformed strata which he correlates with the Fort Union of Montana, and he dates the Laramide disturbance as post-Fort Union (41,d). The Fort Union formation is generally accepted as Eocene (47,a) and if this be so, the Laramide revolution is not older than early Eocene. Schuchert, however, argues with a good deal of force from the evidence given by Stanton (47) for the Cretaceous age of the Fort Union formation (48). An excellent discussion of the debatable strata between the Cretaceous and the Tertiary is given by Rose in his report on the Wood Mountain-Willowbunch Coal Area, Saskatchewan (54).

The most definite statement regarding the date of the Laramide revolution in this region that can be made from the evidence in hand is that it is later than Fort Union and earlier than the quartzitic conglomerate of the Cypress hills. Neither its earlier nor its later limit can be more definitely stated than this. A reasonable interpretation of the stratigraphic evidence summarized above places the Laramide revolution as not earlier than the uppermost Cretaceous, nor later than the latest Eocene.

Before proceeding to a discussion of the present structure of the Rocky mountains and its origin, it may be noted that the history of the region as described here agrees closely with its physiographic development as deduced by Schofield from facts gathered in the Selkirk and Rocky mountains. For the Tertiary and later history, works by Dawson (13,14), Willis (45), Daly (12), (46), Stewart (41), and Schofield (49) may be consulted.

Structural Geology

Structural Features of the Region

General

The Rocky mountains between the International Boundary and the Crowsnest pass may be divided structurally into three areas. These structural areas, the geographic relations of which are shown in Fig. 1, will be designated as the western area, the central area, and the eastern area. From the boundary to the North Kootenay pass the three areas are clearly defined; north of this pass the eastern area is characteristically developed, but the distinction between the central and the western areas is not at present clear, if indeed a distinction exists in this part of the region.

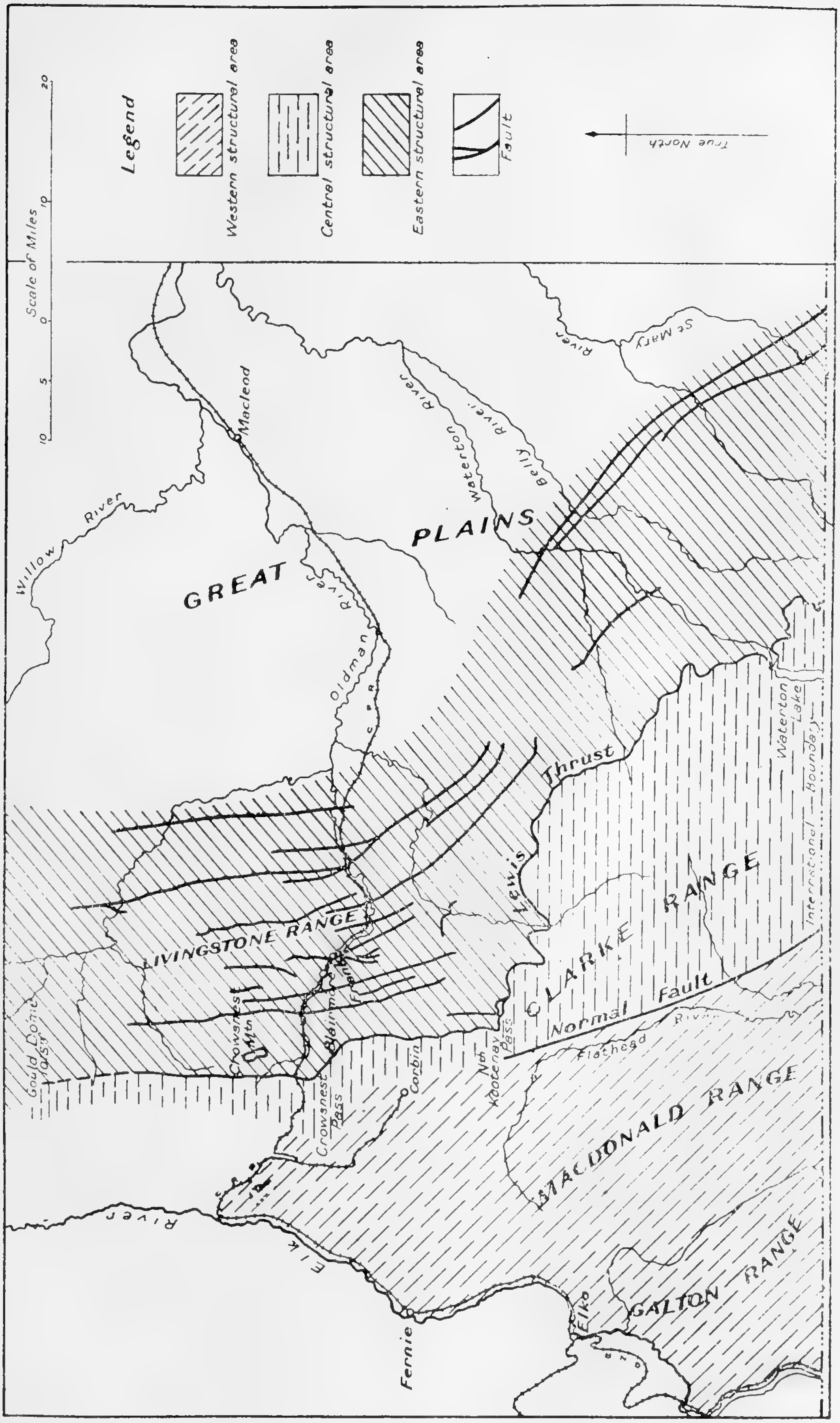

Figure 1. The three structural areas of the southern part of the Rocky mountains in Canada.

The Western Structural Area

The clearly defined portion of the western area, as distinguished from its less definite northward extension, lies between Elk and Kootenay rivers on the west and Flathead river on the east. It is characterized in its southern part by homoclinal fault-blocks separated by large normal faults (12,j), (26,c). Farther north folding is the more characteristic structure, but there is also normal faulting (23). At the boundary the surface rocks of the western area are Precambrian, but northward younger ones appear, and Cretaceous measures are exposed in the Crowsnest pass.

The Central Structural Area

At the boundary the central structural area is a great syncline of Precambrian strata, and this general structure probably holds as far north as the North Kootenay pass. The boundary between the central and the western structural areas in this distance is a great normal fault or zone of faults along the east side of Flathead valley. These faults have a downthrow to the west, so that, as Daly has pointed out, the Clarke range—the central area of this paper—"is in what may be called horst relationship to the block underneath the Flathead valley (12, k)". From the North Kootenay pass to the Crowsnest pass the central structural area is very much narrower than it is farther south, because of the wide western swing of the Lewis thrust at this point. The eastern part of this huge syncline of massive Precambrian sediments, and perhaps the whole of it, is thrust over Cretaceous rocks to the east on a thrust surface of very great extent, the outcrop of which forms the eastern boundary of the central structural area. This enormous displacement is known as the Lewis thrust and its sinuous outcrop has been traced for many miles in Montana and Alberta.

The Eastern Structural Area

The third and eastern structural area consists principally of the foothills of western Alberta adjacent to the Crowsnest pass. In it also is included a part of the Great Plains immediately adjacent to the mountains for 20 miles north of the International Boundary. In this area foothills are lacking, but geologically the region belongs to the "disturbed belt".

In the eastern structural area the rocks are Cretaceous, except for a few areas of Devono-Carboniferous limestone in the Crowsnest pass, and some Eocene beds near the eastern edge. Structurally it is characterized by numerous nearly parallel reverse strike faults, of great length and unusual steepness. These faults are associated with strong folds (34), (41), (24, c). The faulting is more pronounced in the vicinity of the Crowsnest pass than it is near the boundary where the Cretaceous rocks are not disturbed to the extent that they are both to the north and to the south of the international line. The principal faults of the area are shown in Fig. 1. As the hypotheses of the development of the present structures of the region are largely dependent on the characteristics of these faults, they will be described in some detail.

Reverse Faults

Extent.—These faults extend for miles, many of them for dozens, and some of them for scores of miles, and throughout nearly the whole of their extent they closely parallel the strike of the rocks. At their ends, however, where they vanish in folds, there is of necessity a discordance in strike.

Characteristics of the Parting Surface.—There is surprisingly little disturbance of the strata in the neighbourhood of these faults, and breaks of several thousand feet displacement take place on what is apparently a single surface, or in a zone at the most not over a few feet thick. A similar effect has been noted by Stebinger in Montana (40, a). Occasionally along the course of a fault there are what may be termed "zones of regional brecciation" where there is much minor reverse faulting along the line of a single break. Two of such zones are shown on Rose's map of the Blairmore area, one east of McGillivray ridge and one on York creek, and I have seen similar occurrences in the foothills south of the Blairmore area. It is possible that this "regional" brecciation is a more common occurrence than has been recognized, but in general, the faults are probably simple breaks.

Near the main line of the Canadian Pacific Railway in the Rocky mountains McConnell has noted that faults occur "without much preliminary bending" (21, a). It is worth noting in this connection that one of Cadell's experimental results was that reverse faults often develop on the application of horizontal pressure without previous folding (7).

Dip.—Apart from their great length, the high angle of dip of these faults is their most striking characteristic. Though low angle faults have been recognized in the eastern structural area, they are exceptional (24, c), (41, e). These low angle thrusts are readily recognized by their sinuous outcrops, whereas the steeper reverse faults are remarkably straight, even in a region of considerable relief (34), (24, c). This linear outcrop cutting across an irregular terrane is proof that they are breaks along a very even surface of parting, and that this surface now stands at a high angle of dip. The fact that these faults are steeply inclined at the surface is, of course, no guarantee that they maintain this attitude indefinitely, and they probably dip at flatter angles at depth. But when many faults, at different topographic elevations, and separating widely different geologic horizons, are all steep, then they must be supposed to remain steep for hundreds, if not thousands of feet, and a common cause for this attitude must be sought.

A measurement of 22 faults in the sections of the western part of the Blairmore sheet gave an average dip of the *reverse* faults of slightly over 70 degrees, which is nearly twice the average dip of reverse faults as stated by Leith (20, a). The average angle of inclination of the strata which they cut to these same fault planes is just under 31 degrees, which is not far from the average dip of reverse faults. This angle of 31 degrees between the dips of the strata and the fault is believed to be significant, and furnishes one of the clues to the explanation of the anomalous attitude of the reverse faults, and of the general structure of the region.

A prominent feature in the northern part of the eastern structural area, so well shown on Rose's map of the Blairmore area, is the Turtle Mountain anticline. The southern half dozen sections of this map illustrate another general structural feature of the region connected with this anticline. These sections show that the western limb of the anticline is formed of steeply dipping fault blocks of repeated strips of strata, whereas the eastern limb is more folded than faulted, and the strata are in general much flatter, though the folding is irregular in detail. The southern continuation of this anticline exhibits a similar though a less pronounced relation of a steeper western and a flatter eastern limb (24, c). This steep western and flat eastern limb is an effect that would be caused, leaving the faulting out of consideration, by the westward rotation of a previously formed symmetric anticline.

The Lewis Thrust

The salient features of this great overthrust are of such importance in a consideration of the structural features of the region that they will be given here.

Extent.—The Lewis overthrust (see Fig. 1) was first recognized and named by Bailey Willis in northwestern Montana in 1901 (45, f). In 1906 Daly traced the thrust into Alberta (12, h) and in

1912 I observed a fault which I correlated with the Lewis thrust in the North Kootenay pass and in the country south of it (24, a). Later work by Stewart has confirmed this correlation (41, e) and his map has filled the gap between my own work and that of Willis and of Daly.

Dr. Bruce Rose informs me in a personal communication that the Lewis thrust continues northward from the North Kootenay pass at least as far as Gould Dome, near latitude 50 degrees, and that it may even extend fifty miles farther north to the Kananaskis river. The field evidence in this region is not yet definitely worked out. If it does not continue northward as a single thrust phase, the break is represented by other similar overthrusts.

In Montana, Campbell shows the outcrop of the thrust surface extending southward to the southern edge of the Glacier National Park (9, a). The known length of the fault, measured in the general direction of its outcrop, without regard to the sinuosities of its course, is 50 miles in Montana and 85 miles in Alberta, 135 miles in all. Its total length, however, is somewhat greater than this, for as mentioned above it may extend northward for some miles from Gould Dome, and it probably runs south of its southern mapped position. In Montana the general direction of the outcrop is north 30 degrees west, except for the deep re-entrant at the southern end, where it runs north 35 degrees east for 15 miles. As only the northern side of this re-entrant is mapped, it is not known whether this is really a change in the strike of the fault or a change in direction caused by topography. In Alberta virtually the same direction of 30 degrees west of north is maintained to the headwaters of Pincher creek, 30 miles north of the boundary. From here the strike swings gradually more to the westward, and runs about north 80 degrees west to the North Kootenay pass, a distance of 23 miles. Here it turns sharply due north and maintains this direction to Gould Dome, except for an offset of three miles to the westward in the Crowsnest pass. If the break extends north of Gould Dome the strike is a few degrees west of north.

Characteristics.—From its southernmost located position to the North Kootenay pass, a distance of about a hundred miles, the Lewis thrust is found at or near the base of the front ranges of the Rocky mountains, and, as Willis explains (45, g), the topographic relations of the front ranges adjacent to the boundary are dependent on the position and attitude of the thrust surface. North of the North Kootenay pass the thrust lies behind the front ranges of the mountains, these being the Livingstone range continued northward in the

Highwood range. These relations are evidence that the Lewis overthrust is thus an integral part of the structure of the mountains themselves, and is not found only where the mountains join the plains.

Wherever it has been observed, this overthrust has reversed the normal superposition of the strata, and normally lower rocks have been pushed up to and over the Cretaceous measures. For many miles in Montana a considerable thickness of the Altyn limestone, one of the oldest Precambrian formations, rests on the Cretaceous (45, f), and a similar relation has been noted by Daly in Alberta (12, h). In the North Kootenay pass, rocks correlated with the Siyeh of the International Boundary section overlie the Kootenay formation of the Cretaceous (24, a). The stratigraphic distance between the Altyn and the upper Siyeh is 7,500 feet, so the relations given above are evidence that the stratigraphic break along the thrust surface is lessening toward the north. The Precambrian rocks do not extend as far north as the Crowsnest pass, and Dr. Rose in a personal communication states that the Lewis thrust "continues northward, cutting across the formations in ascending order, and at Crowsnest lake the Devonian lies on Belly River (Allison formation) sandstone." He also states that the flat thrust under Crowsnest mountain (50, a), if not the Lewis, is a lower, parallel thrust. It is clear, therefore, that the break along the Lewis thrust lessens in magnitude as it is traced north, and Dr. Rose suggests that the main Lewis thrust of Gould Dome may be represented by some very complex faulting and folding farther north (*cf.* 33, a).

The nature of the thrust surface has been described by Willis as warped, and he gives some graphic determinations of its attitude south of Chief mountain in Montana (45, h). In general the thrust surface has a very low westward dip. Although in any area of a few square miles the surface is warped, when the very great extent of the break is considered it is apparent that the surface taken as a whole is a remarkably even one. The actual distance that the overthrust mass moved cannot now be demonstrated, but at the southern end of the Glacier National Park it is at least 15 miles (9, a). Farther north a shift of 7 miles has been observed (45, j) and Daly makes the interesting suggestion "that the entire Clarke range in this region represents a gigantic block loosed from its ancient foundations, like the Mt. Wilson or Chief Mountain massifs, and bodily forced over the Cretaceous or Carboniferous formations. In that case the thrust would have driven the block at least 40 miles across country" (12, b).

The displacement is known to be at least 15 miles; and in view of the stratigraphic break of many thousands of feet, the low dip of the fault surface, and its great lateral extent, Daly's suggestion may be considered within the bounds of possibility.

Structure Above the Thrust.—In the vicinity of the North Kootenay pass in Alberta there is no apparent disturbance of the beds above the thrust surface that would indicate the presence of such an enormous dislocation of the strata. The evenly layered sediments are here traversed by numerous regular joints approximately at right angles to the bedding. It is possible, however, that subsidiary slips and fractures may be found on closer study. Near the 49th parallel significant minor structures—minor only in comparison to the greater break—have been described. Willis gives a clear description of these structures above the break as observed by him, and his account is quoted here (45, k).

The detailed structure of the Algonkian mass above the Lewis overthrust is sometimes chaotic when considered in the small, yet simple when observed in the large. The chaotic structure is best exhibited in Chief mountain where the lower massive member of the Altyn limestone is crushed. The fractures divide the masses irregularly into blocks of all angular shapes varying from a few inches to 25 feet on a side. The surfaces are slickened over wide areas, and where they preserve their orientation in the cliffs the slickens demonstrate much relative horizontal displacement of adjacent fragments. Certain fracture planes are in fact steep fault surfaces along which displacement has occurred in the direction of the strike rather than in that of the dip. Such faults are, however, without apparent system. In other places, as north of Altyn, the cliffs present mural faces traversed by remarkably regular lines of bedding which are crossed by nearly vertical joints.

Viewed in the large, the structure of the Altyn limestone sometimes is that of major and minor thrust faults. Yellow mountain, as seen from Chief Mountain ridge, exhibits these relations very clearly. The basal major thrust lies at the foot of the cliffs, somewhat obscured by talus, but sloping about 8 degrees in a curve which on the left is less inclined and descends more rapidly to the right. Springing from it are several minor thrusts, which dip more steeply and which upward pass out either into the air or into an upper major thrust. The upper major thrust is at the base of the argillites which dip gently and without appreciable disturbance to the southwest. It simulates an unconformity.

In Chief mountain a similar structure is more strikingly exhibited. The base of massive Altyn limestone is traversed by minor thrusts which are often subparallel to the bedding, so far as it can be made out. These thrusts dip 30 degrees and occupy a zone about 1,000 feet thick above the Lewis major thrust. They are limited above by an upper major thrust which is at the base of nearly horizontal thin-bedded limestones, constituting the upper member of the Altyn formation.

The thickness of strata within which major and minor thrusts are developed is by no means constant. As stated, near Altyn the lowest beds of Altyn limestone present mural regularity of structure, whereas in Yellow mountain probably not more than 500 feet of strata are so repeated as to pile up 2,400 feet high. West of Waterton lake, in the section seen by Dawson, the effects of minor thrusting are still greater; but, though the resulting pile of overthrust segments be great, the maximum thickness of strata involved is probably less than 1,000 feet.

Above the zone of minor thrusting as limited by the upper major thrust the strata are not notably dislocated, if at all, on planes of overthrusting. Nevertheless, it is important to state, as bearing on the distribution of that stress which produced the thrusts, the fact that dividing planes which are parallel to the Lewis overthrust, traverse the higher Algonkian strata in the heart of the syncline. The appearance of these planes which may be called X planes, is given in photographs from near Swift Current looking southwest. They were also sketched from Trapper peak looking south. In both cases they appeared as elements of the profile or as snow-covered benches on the faces of the cliffs. They cross the stratification, indifferent to the direction of dip. With the field glass no displacement along them could be made out. Nevertheless, whether the strain exceeded the limit of rupture or not, it follows from the parallelism of the X planes and the Lewis overthrust that the stress which produced the system was effective throughout the mass. Between the highest X planes in Mount Reynolds, in the upper part of the Siyeh limestone, and the Altyn limestone at the Lewis thrust, the thickness of strata is something more than 8,000 feet.

Structure Below the Thrust.—The structure of the Cretaceous strata below the thrust can be actually observed in a relatively narrow zone adjacent to it, and partly overlain by the overthrust block. This zone has certainly been overridden by the superposed strata. The strata beneath the overthrust block west of the outcrop of the thrust can only be conjectured, but for some distance it can be reasonably supposed to be similar to that in the visible zone. The structure of the country east of the certainly overlapped zone can be deciphered accurately, but the extent to which this country was formerly covered by the overthrust mass can be stated only as a matter of theory. It may be accepted as beyond doubt, however, on the basis of the evidence now in hand, that the overthrust mass formerly extended farther eastward than its present position. This former eastward extension has been removed by denudation.

In northern Montana, Willis considered the attitude of the Cretaceous underneath the thrust to be a monocline of simple structure dipping southwestward (45, g), though he recognized some complications, which, owing to the paucity of outcrops, could not be worked out. Later more detailed work by Stebinger in the same region has demonstrated that immediately adjacent to the mountains the structure is more complicated than Willis had supposed. He states (40, a)

Minor undulations of the strata in the area of nearly horizontal rocks can be seen in detail only along the principal stream valleys. They are gentle monoclinal flexures in which the inclined beds are on the west, although in a few places reverse dips produce slight anticlinal folds in the generally westward-dipping rocks. The change in structure from the nearly horizontal rocks in the eastern half of the reservation to the steeply dipping disturbed rocks in the western half is very abrupt. Where exposures are good, especially along the major stream valleys, this change can be seen to occur within a few feet, there being no intermediate zone of gentle folding.

The disturbed belt of rocks adjacent to the mountains occupying the western third of the region here described is a small part of a structural area from 15 to 20 miles wide, lying at the base of the Rocky mountains, which extends at least 80 miles southeastward to and beyond Sun river and a much greater distance northwestward across Alberta. Throughout this area the rocks have been intensely folded and faulted by thrust stresses that acted from the southwest. In many places the individual formations are so much crushed and broken that it is impossible to identify them with certainty. The one constant feature in this whole disturbed area is the uniform northwesterly strike of the rocks. Because of this parallelism of strike the more resistant sandstones of the several formations appear as numerous parallel strike ridges, the same formation being repeated within short distances.

The disturbed belt mentioned by Stebinger as extending into Alberta has been studied in some detail by several workers in that province. This area forms the eastern structural area of this paper. It is to be recalled that the western portion of this belt is certainly the overthrust mass of the Precambrian strata, and that it was formerly covered by this block to a greater extent than is now the case. Its structures, therefore, are to be considered as underlying the thrust surface, and any hypothesis explaining the mechanics of the overthrusting must give them weighty consideration.

Date of the Lewis Thrust.—From considerations which were fully discussed above it was concluded that the Laramide revolution took place not earlier than the uppermost Cretaceous nor later than the latest Eocene. The interpretation of the structural history of the region as elaborated in this paper indicates that the Lewis thrust was one of the latest effects of the compressive stresses of the Laramide revolution. Its age can not be fixed precisely from the evidence in hand, but a probability of Eocene date is indicated. That it took place before the deposition of the conglomerate of the Cypress hills seems established beyond doubt.

In the Rocky mountains of Idaho, Montana, and Wyoming several similar flat overthrusts have been studied, one at least of which, the Heart Mountain thrust, is comparable in its dimensions with the Lewis thrust. The age of these great breaks has been determined from stratigraphic evidence which is in general more conclusive than that on which the age of the Lewis thrust is based.

In southeastern Idaho, Richards and Mansfield date the Bannock overthrust before the deposition of the lower Eocene Wasatch beds (31). In southwestern Wyoming Veatch dates the Absaroka thrust in the lower Eocene (42). In northern Wyoming Hewett places the

Heart Mountain overthrust between the middle and upper Eocene, and in Montana the Lombard overthrust has been placed with some uncertainty by Haynes in the very late Cretaceous or early Tertiary (15). It is probable, as Hewett states (16, a), that these faults did not take place simultaneously. It is, perhaps, not to be expected that they should so form, even though they are all effects of the same cause—the compressive stresses of the Laramide revolution. It is reasonable to suppose that these stresses were relieved by periodic slipping in certain regions at slightly different times. This may have been the case, so that the Lombard and Bannock thrusts, taking place before the Eocene (though not necessarily simultaneously) relieved the stresses for a time, and later, reaccumulated stresses caused the Lewis, Absaroka, and Heart Mountain overthrusts to form. This interpretation agrees with the suggestion of Dake that it is "quite improbable that these various faults will ultimately be found to be part of one great overthrust" (11).

Structural Geology. Development of the Structure

The general structural features of the southern Rocky mountains of Canada have been summarized in the foregoing statements in order to present a basis of facts for the hypothesis which is put forward to explain the present structures and physiography. The significant structural elements to consider are three areas: (1) a western area, with structures characteristic of tension following compression; (2) a central area, with structures characteristic of severe compression; and (3) an eastern area, the structures of which are not readily to be explained. An hypothesis interpreting the development of the structure of the mountains must explain each of these three zones, and its relation to the others, and the structures found in them. Such an hypothesis is presented in this paper. As Willis has given an interpretation of the structure of the Clarke range, and the Lewis thrust, his hypothesis will first be outlined, and the reasons for dissenting from it stated. It must be remembered, however, that his explanation considered only that region in Montana which is the southern continuation of the central structural area of this paper, so it is not as comprehensive a treatment as the one attempted here.

Willis' Explanation of the Lewis Thrust

The paper by Willis, so frequently referred to here, is worthy of the closest study by any one interested in the geology of the region here discussed. His hypothesis as to the existing relief of the Front ranges of the Rocky mountains has been well summarized by Daly (12, f) as follows:

1. The "Algonkian" strata were reduced to a peneplain in early Cretaceous time. This old erosion surface subsided beneath the Benton sea, which extended as far west as about the longitude of Waterton lake.

2. During Dakota and Benton time there was a very gentle and broad upwarp of the Front ranges area, accompanied by sedimentation in a sea which covered only the eastern part of the belt now occupied by the Lewis range.

3. At the close of the Laramie (presumably at the time of the general Laramide revolution) there was a single upwarp of the "Algonkian" and overlying Cretaceous beds, forming an unsymmetric fold with steeper dip on the east.

4. During the early Tertiary a long period of crustal repose during which the upturned rocks were all more or less perfectly planed and the Blackfoot erosion cycle completed. The peneplain was most perfect on the soft Cretaceous rocks, but there was probably "low, hilly, post-mature relief on the Algonkian (Lewis series) rocks."

5. In the mid-Tertiary the great Lewis overthrust took place, whereby the greatly eroded "Algonkian" block of the Front ranges and the equally broad mass of the Galton-MacDonald group were uplifted.

6. Apart from local normal faulting, the subsequent history of the region has consisted in steady erosion, leading to mature mountain topography.

In explaining the Lewis thrust, it is clear that Willis considered it to be of the type to which he had long before given the term "erosion thrust" (44, a). It is doubtful whether he considered the structure of the Cretaceous rocks of the eastern belt as defined above to be the factor of prime importance in the explanation of the structure of the region, that it undoubtedly is. For example, in describing the structures beneath the Lewis thrust, he states (45, g): "The structure of the Cretaceous beneath the Lewis thrust was not connectedly observed. . . . Out of perhaps twenty reliable observations of dip, distributed over the entire area of Cretaceous sub-terrane, nine-tenths are to the southwest and are from a degree to 25 degrees. *In the field the monoclinal southwestern dip was taken to be a simple structure.*" (The italics are mine). He recognizes, however, that this supposed monocline is complicated either by eastward dips in part of the area or by other overthrusts.

The Cretaceous area adjacent to the International Boundary studied by Willis has a more simple structure than has the Cretaceous either to the north or to the south. The simple structures at the boundary are not characteristic of the disturbed belt of the Cretaceous either in Montana or Alaska.

The three fundamental assumptions on which Willis based his explanation of the structure of what is here termed the Central area, as stated by himself (45, a) are: "(*a*) The thrust surface coincides essentially with the bedding of the Algonkian series. (*b*) It coincides essentially with the highest peneplain in the Cretaceous rocks. (*c*) The antecedent structures of the Lewis thrust were determined by conditions of deposition."

Of these three assumptions, the first may be admitted to be substantially true in the direction of the strike at any rate, though the rise of the fault surface from the boundary northward as described above, is to be noted. This of itself does not invalidate Willis' hypothesis. The third assumption which is a generalized statement of Willis' theory of initial dips, may be admitted to have been a controlling factor in the localization of certain structures, though it may not have functioned in the way premised by Willis. The second assumption, that the thrust surface coincides with an early Tertiary peneplain, is the one really essential to Willis' hypothesis. The existence of this peneplain is necessary to his explanation of the Lewis overthrust as an erosion thrust and if the peneplain did not exist his hypothesis is not tenable. An examination of the evidence based on my own field work and that of others leads me to believe that this Tertiary peneplain in the Rocky mountains did not exist, and consequently some other explanation of the structures and present relief of the region is required. The evidence may be summarized here.

The stratigraphic facts given in a preceding part of this paper are indicative of virtually continuous sedimentation from the later Cretaceous up to the Paskapoo beds of Fort Union age. The Fort Union is generally accepted as Eocene (47, a), though Schuchert, as noted above, argues from Stanton's evidence (47) for its Cretaceous age. The Paskapoo beds are the latest ones deformed by the Laramide revolution. As no general erosion took place before their deformation, it is clear that the supposed peneplanation must have taken place after the uplift consequent on their deformation. If Schuchert be correct, this deformation may be of pre-Eocene age; if the generally accepted view be taken, it is of early Eocene date.

It was demonstrated in a previous section that the Lewis thrust was completed before the end of the Eocene. The time available for the peneplanation that Willis supposes to have preceded the Lewis thrust is thus narrowed to a limited interval during the Eocene. When one reflects that on any hypothesis, all of Quaternary, and at least half of Tertiary time have sufficed only to produce the present extreme relief, the time allowed according to the stratigraphic evidence given above, seems insufficient to cause peneplanation. The stratigraphic facts further indicate that the Lewis thrust followed a period of deposition, rather than one of erosion.

The foothills south of Blairmore, Alberta, are "characterized by a parallel series of ridges, often maintaining uniform heights for several miles; attaining an altitude of 6,000 feet or more in the western part of the area, where they are often of knife-like sharpness, and gradually decreasing in elevation and steepness of slope as the plains are approached (24,d). The fact that the ridges are higher and steeper in that part of the area adjacent to the mountain front is significant, and may indicate that the present foothill region was formerly covered by the overthrust block, which protected the western ridges from erosion for a longer time than it did the eastern ones.

In his discussion of the antecedents of the Lewis thrust by folding and erosion, Willis postulates two episodes of compression, between which the peneplanation took place (45,b). I do not know of any facts in the structure or physiography of the region that necessitate two episodes of compression for their explanation, but on the other hand, all the known facts can be explained on the basis of a single episode. This compression may have begun slowly, continued to a maximum, and ended gradually, or it may have been pulsatory. Reasoning from what we know of the larger geologic processes, the latter is the more probable supposition, but that there was any sufficient interval between pulsations for peneplanation to take place is not considered probable. Evidence for two episodes of compression during the Laramide revolution is known from Wyoming (51), but the two are very close together, and may be considered as effects of the usual rhythm of geologic processes. Willis, on the other hand, supposes a first episode in the early Tertiary causing moderate folding (45,c) and that this folding was followed by a quiescent period long enough for peneplanation. Moderate folding in the Cretaceous is true only for a limited area adjacent to the boundary. The structure of the Cretaceous in general is that of strong folds and steep reverse faults of large displacement, so that according to his hypothesis, the region must first have been mountain-built to a large degree during the first period of compression in order to give the structures now found in the Cretaceous of southwest Alberta, and then a great deal of erosion must have taken place to peneplain these mountains. The time that can be allowed for this erosion, a limited interval preceding or early in the Eocene, as demonstrated above, is hardly sufficient for peneplanation of a mountain-built region.

The evidence with regard to an early Tertiary peneplain in the Rocky mountains, as recapitulated above, shows that the stratigraphic facts do not allow of sufficient time for it to have formed; the physiography does not require a peneplain for its explanation, and the structural facts are inconsistent with its existence. Daly has discussed the subject at length on different grounds, and has reached the same conclusion. His account is here quoted in full. After summarizing the hypothesis of Willis' paper as given above, he says (12,f):

In passing, it may be noted that the evidence of the earlier Mesozoic peneplain on which the Dakota and later Cretaceous beds were deposited, is not made clear. It would seem probable that during the Mesozoic, this part of the Cordillera was never far above sea-level. Most of the Mississippian limestone formation is still preserved in the Crowsnest district only fifty miles to the northward on the strike of the range. To the southeast its equivalent is likewise preserved beneath the Cretaceous beds of the Belt mountains. We have seen that a great thickness of the Mississippian limestone persists in the fault-blocks of the MacDonald range just across the Flathead. Nowhere in the eastern part of the Cordillera north of Colorado is there evidence of notable deformation of the Rocky Mountain Geosynclinal between Mississippian and Laramie times. It seems likely, therefore, that a great thickness of the Mississippian limestone was present in the MacDonald range area before the Laramide or post-Laramide faulting dropped the large masses of the limestone into lateral contact with the Altyn formation of the MacDonald range. If this be granted, it follows that little erosion had been accomplished in this latitude during the Mesozoic. The Mesozoic erosion-cycle could not have very great significance in the region.

Returning to the main theme, we may note that Willis's evidences for the mid-Tertiary peneplanation are: (*a*) the truncation of the crumpled Cretaceous; (*b*) the presence of accordant levels among the summits of the Galton-MacDonald mountain group. Concerning the first point, it is not made certain that the truncation of the Cretaceous was observed outside the area which may reasonably be supposed to have been overridden by the overthrust block of the Front ranges. This thrust, as shown at Chief mountain very clearly, has not only crumpled the Cretaceous beds but has sheared them off sharply at the plane of the Lewis thrust. In some measure the observed truncation elsewhere may be attributed to this constructional process, for there is clear evidence that the original eastern edge of the overthrust block lay several miles to the eastward of the existing frontal escarpments of the Lewis and Clarke ranges. Of course, erosion has modified the surface of scission thus exposed by the retreat of the escarpments, but its base-levelling effect must here have been vastly inferior to that which was demanded on the hard quartzites and siliceous dolomites of the Lewis series.

The argument from the accordance of summit levels cannot, in the writer's opinion, be safely applied in any one of the four ranges now in discussion. In no one of them is there any notable remnant plateau which can fairly be said to prove general base-levelling in a former erosion cycle. The writer has already published the grounds of his protest against using the accordance of peaks and ridges as an evidence of two erosion cycles; a full abstract of that publication will be given at the close of this chapter, to which the reader may turn. In brief, the point is made that sub-equality of heights is to be expected from the early stage in the history of every alpine mountain range.

The evidences against the hypothesis of a mid-Tertiary peneplain on the Front ranges seem to be powerful. First, the time allowed is not sufficient for peneplanation or even past-mature development, followed by uplift and mature dissection in a second cycle. All post-Cretaceous time has not been enough to destroy the large monadnocks on the well-established Cretaceous peneplain of the Appalachians, though their rocks are not sensibly stronger than those of the Front ranges of the Cordillera. In most of the Appalachian belt a very large percentage of all Tertiary time has sufficed to do no more than form mature or submature topography through the dissection of the generally well elevated Cretaceous peneplain. Yet the climatic and other erosion conditions are not now very different, and probably have not been very different, in the two mountain-chains throughout the Tertiary. It seems, therefore, hard to believe that the exceptionally tough rocks of the Front ranges at the Forty-ninth Parallel have been peneplained once and maturely dissected afterwards since the close of the Laramie period.

Again, the general lack of stream adjustment in the entire section from the Great Plains to the Flathead trough is a valid reason for rejecting the two-cycle hypothesis. Difficult as it is to be sure in the case, it seems that most of the drainage is of consequent origin. Contrast with this condition that of the middle Appalachians, where subsequent drainage is probably dominant over all other kinds of drainage. In this region of two cycles there has been time enough for head-waters to lengthen the streams by gnawing back into the soft belts for even scores of miles. Yet the second important cycle is still not past maturity. Well-developed subsequent drainage is the role in many parts of the Appalachians where the rocks are all hard in an absolute sense, though differing relatively in power to resist erosion. In the Front ranges of the Cordillera the rocks are all strong, but he is bold who would deny that some are notably weaker than others and should thus ultimately guide headward growth of streams in a two-cycle period of time. Failing such manifest guidance along the strike of certain beds of the Lewis series, it must be said that this well recognized criterion of multiple cycles (so justly emphasized by Davis and others) does not favour the idea of a mid-Tertiary peneplain in the Front ranges.

Finally, the one-cycle hypothesis, whereby only one major episode of deformation (the Laramide) and one erosion-cycle (including all of Tertiary time) are postulated, seems competent to explain the present topography.

The accordance of summit levels is here partly implied in the relatively small degree of deformation other than uplift; for the rest, it is explicable on the composite hypothesis discussed at the close of the chapter.

The bevelled surface of the Cretaceous may truly mean a widespread peneplain on the soft rocks of the Great Plains, but it by no means implies a peneplain on the much harder rocks of the Front ranges. The erosion of both provinces has been chiefly occasioned by rivers and creeks issuing from the mountains. In the mountains these streams have high gradients but small volume; outside the mountains, tolerably swift currents and much greater volume. It seems necessary to believe that on the plains these streams would, through lateral corrasion, develop a peneplained surface with relative rapidity. In the mountains the threads of water must develop such a surface from rocks like those of the Lewis series, with immense slowness. Willis's argument that it is unlikely that the peneplain formed on the Cretaceous of the plains should not adjoin a rugged, scarped mountain range of contemporaneous development seems to be a very doubtful one, in view of the fact that the precisely similar relation is seen in the case of the dissected Niagara escarpment overlooking the Tertiary lowland of New York and Ontario. Similarly, the Catskill escarpment overlooks the Tertiary lowland of the Hudson valley, and the crystalline terranes on each side of the Connecticut valley dominate the peneplained Triassic sandstone of that valley. In these Appalachian cases we cannot doubt that the upper facets are of Cretaceous date, the lower peneplains of relatively late Tertiary date; that is, they have a great contrast of age, and one which is significantly like that suggested by the writer for the flat erosion-surface of the Great Plains and the adjacent blocks of the Front ranges. Furthermore, the eastern slope of each Front range is generally a retreating escarpment and, as already noted, the retreat is to be measured by miles, perhaps by many miles in some places. The structure of the region, with soft underlying hard at the Lewis thrust, necessarily involves a steep retreating mountain-front so long as the thrust-plane remains above base-level. The case is again analogous to the Catskill or Niagara escarpment except that in those cases the erosional undermining is controlled by bedding and not by a flat plane of overthrust.

Again, the dissection of the Front range blocks is just of the order of magnitude expected from the analogy of lithologically somewhat similar Appalachian terranes, which have been maturely dissected in a well dated erosion cycle occupying the larger part of Tertiary time.

Since the character of the drainage is apparently that to be expected on the one-cycle hypothesis for the region, it seems that all the essential topographic features are explained by that hypothesis. The writer believes that no proved structural relation in the bed rocks needs the two-cycle hypothesis for its explanation. In conclusion, therefore, he would state his belief that the Front ranges, as well as the Galton-MacDonald group, were uplifted in the one episode of the Laramide orogenic revolution and have undergone steady erosion ever since, this erosion reaching maturity and no later stage. It is possible that an horizontal thrust has deformed the unconsolidated Miocene clays of the Flathead trough, but there is no clear evidence that this movement affected the great blocks to east and west in any essential way.

The argument has been dwelt upon not only because the physiographic history is also the geological history of the Rocky Mountains proper, but also because a similar history may be credited to the broad Purcell Mountain system, to the brief discussion of which we may turn.

Suggested Explanation of the Structure

The present structural features of the region can be explained by a 1 hypothesis which assumes that they were caused by compressive stresses acting in an easterly direction during a single orogenic episode (35,a). It is, however, not vital to the hypothesis that the pressure from the west was continuous from its inception to its decline; it may be, and probably was, rhythmic, but there was no long period of quiescence between pulsations, and the episode is single in the sense that from the time the compressive forces of the Laramide revolution began to deform the strata until they finally ceased to act, continual deformation characterized this geologic event.

The mass on which the compressive stresses acted consisted of a virtually parallel accumulation of strata many thousands of feet thick, in general more massive and, therefore, more competent in the Precambrian lower and Palæozoic middle portions than in the

Mesozoic upper beds. A feature of the general structural relations that seems anomalous is the fact that the most severe deformation is now exposed in the eastern zones of the disturbed area, or those farthest from the old land to the west from which the thrust presumably came. Experimental work indicates that horizontal stresses are not propagated far forward into a mass of strata (7), yet the field facts indicate that if the stress did come from the old land, its effects were felt many miles to the eastward. It may be that the especially competent Precambrian and Palæozoic limestones, thickened and strengthened by the earlier events of compression, did transmit the forces far eastward, or it may be that an access of stress, acting from below diagonally upward in the neighbourhood of the MacDonald range, severely compressed the zones to the east. Stresses were, at any rate, acting in an eastward direction throughout what is now the Rocky mountains.

The structures exhibited by the central and eastern structural areas of this region when considered as a whole, bear a remarkable similarity to the structures of certain areas of the greatly overthrust portions of the northwest highlands of Scotland. In the monumental memoir of the Geological Survey of Great Britain on the geological structure of the northwest highlands of Scotland (29) numerous figures are given which illustrate the occurrence of flat overthrusts of large displacement underneath which are very steep reverse faults of small displacement. The scale is, of course, less in the Scottish examples than in the Rocky mountains, and the intensity of overthrusting and accompanying reverse faulting is much greater, as there are several major overthrusts overlapping in Scotland where one only is known in Alberta. In spite of these differences, however, the essential features of the two regions are similar.

Although the structures of the Rocky mountains are on a larger scale, their relatively greater simplicity invites an explanation of the mechanism of their formation along the lines suggested by the experiments of Cadell (7), whose summarized conclusions are given here (20, b).

1. Horizontal pressure applied at one point is not propagated far forward into a mass of strata.

2. The compressed mass tends to find relief along a series of gently-inclined thrust-planes, which dip towards the side from which pressure is exerted.

3. After a certain amount of heaping-up along a series of minor thrust-planes, the heaped-up mass tends to rise and ride forward bodily along major thrust-planes.

4. Thrust-planes and reversed faults are not necessarily developed from split overfolds, but often originate at once on application of horizontal pressure.

5. A thrust-plane below may pass into an anticline above, and never reach the surface.

6. A major thrust-plane above may, and probably always does, originate in a fold below.

7. A thrust-plane may branch into smaller thrust-planes, or pass into an overfold along the strike.

8. The front portion of a mass of rock being pushed along a thrust-plane tends to bow forward and roll under the back portion.

9. The more rigid the rock, the better will the phenomena of thrusting be exhibited.

10. Fan-structure may be produced by the continued compression of a single anticline.

11. Thrust-planes have a strong tendency to originate at the sides of the fan.

12. The same movement which produces the fan renders its core schistose.

13. The theory of a uniformly contracting substratum explains the cleavage often found in the deeper parts of a mountain system, the upper portion of which is simply plicated.

14. This theory may also explain the origin of fan-structure, thrusting, and its accompanying phenomena, including wedge structure.

The significance of these experiments in relation to the region under discussion is that they indicate the possibility of formation, by compressive stress, of steeply inclined reverse faults in connection with flat overthrusts or "soles." This is not meant to imply that the same sort of stress formed the steep faults as formed the flat ones; indeed recent researches by Chamberlin and Miller (10) (see also 41), indicate that the low angle thrusts are found under conditions of rotational strain as contrasted with purely compressive stresses which form the usual type of reverse fault with an angle of dip of something under 45 degrees. The fact that the structures of the foothill belt can be seen to pass under the great overthrust block demonstrates that they antedate the Lewis thrust, though the overthrusting may have modified them. This difference in time of formation, and the difference in stratigraphic position shows that the stresses forming the two types of fault were different.

With the various considerations outlined above in mind, the development of the structure may be treated in narrative style. Two sections across the mountains are illustrated in Figures 2 and 3. Each of these figures shows by means of serial sections the successive stages by which it is imagined the mountains gained their present structure. Both figures are generalized, the intention being to illustrate generalities rather than details. Figure 2 is an east-west section just north of the International Boundary. In this latitude Cretaceous rocks are confined to the Great Plains except for some small down-faulted blocks in Flathead valley. Figure 3 represents an east-west section north of the North Kootenay pass, in which latitude the Cre-

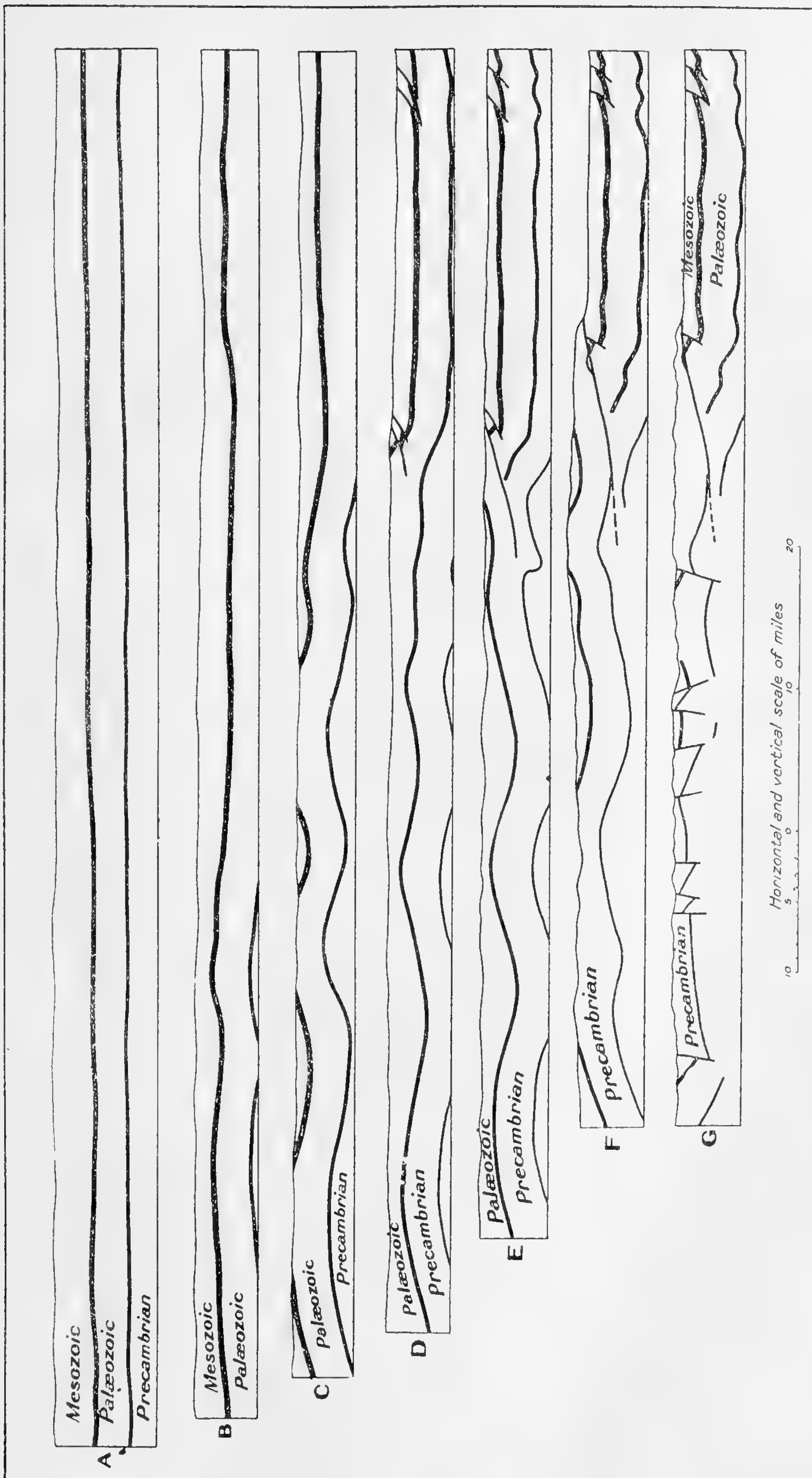

Figure 2. The progressive development of the Rocky Mountain structures at the International Boundary; (A) Section 1, Conditions immediately preceding the Laramide revolution; (B) Section 2, Structure at an early stage in the compression; (C) Section 3, Uplift in the west and steepening of folds by continued compression; (D) Section 4, Reverse faults develop in eastern, less competent strata; (E) Section 5, Continued compression causes pronounced overthrusting and steepening of reverse faults; (F) Section 6, Extensive displacement on the Lewis overthrust; (G) Section 7, Generalized present structure; illustrates normal faulting caused by relaxation of compression.

taceous rocks extend farther across the Rocky mountains than at any other place.

The conditions described in an earlier part of this paper as being those which preceded the action of the first compressive stresses of the Laramide revolution are illustrated in Section A of both figures. The Precambrian strata are taken as 14,000 feet thick, this being the thickness exposed along the 49th parallel, although the base is not exposed (12,m).

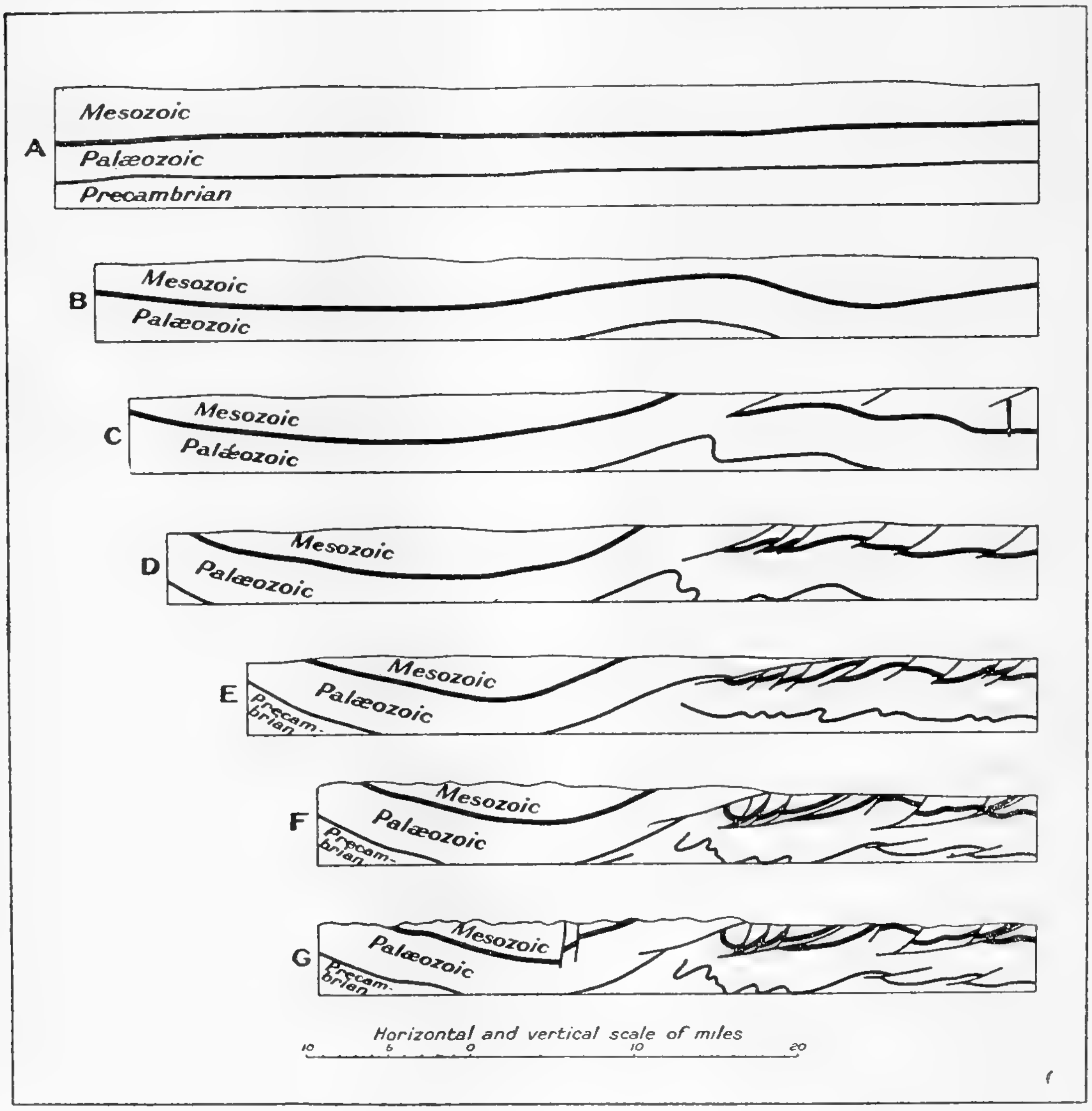

Figure 3. The progressive development of the Rocky Mountain structures at the North Kootenay pass; (A) Section 1, Conditions immediately preceding the Laramide revolution; (B) Section 2, Structure at an early stage in the compression; (C) Section 3, The development of reverse faults caused by continued compression; (D) Section 4, Further compression causes overthrusting, and steepening of reverse faults; (E) Section 5, Formation of 'soles' by continued compression; overthrusting marked; (F) Section 6, Rotation of slices above 'soles' causes further steepening of reverse faults; (G) Section 7, Generalized present structure; illustrates normal faulting caused by relaxation of compression.

The Palæozoic is taken as 15,000 feet thick, a figure which at any rate represents the order of magnitude of the sediments of that era. Near the main line of the Canadian Pacific railway the thickness of the Palæozoic is given as 30,000 feet by McConnell (21,b). The thickness given by Allan in the Ice River area is 28,000 feet for the Cambrian, Ordovician, and part of the Silurian only (3,a). These thicknesses are north of the region considered. In Flathead valley near the boundary there are 5,000 feet of Devono-Carboniferous rocks exposed (26,b), and in the North Kootenay pass there are several hundred feet of Middle Cambrian strata (1). In view of these figures, 15,000 feet is considered a moderate figure for the thickness of the Palæozoic measures. No attempt has been made to indicate variations of thickness in the rocks of this era, though they undoubtedly exist.

The Mesozoic strata are shown as decreasing in thickness from west to east, which is in accordance with what is known of the Kootenay and Fernie formations. As the Mesozoic formations were derived from a westward land mass there is little doubt that the rocks of that era are thicker toward the west. Accordingly they are shown here with a thickness of 15,000 feet thinning to 10,000 feet in the east. McEvoy found 12,000 to 13,000 feet of Cretaceous strata alone in the Crowsnest basin (22a), and Stewart gives a maximum thickness of 12,000 feet above the Fernie in the foothills of southwest Alberta (41,f). The figures used here are, therefore, sufficiently representative for the purposes of this paper.

A significant difference in the method of action of the compressive stresses is apparent from the present day distribution of the Cretaceous rocks. Near the International Boundary Precambrian rocks are at the surface in the western area, while near the North Kootenay pass Mesozoic rocks outcrop all the way across except in the overthrust zone of older strata. Apparently, therefore, compression was accompanied by uplift in the west at the boundary, causing denudation of the higher rocks, while farther north a corresponding uplift did not take place, leaving the Mesozoic rocks still exposed at the surface. It is possible that transverse faulting across the north end of the MacDonald range may in part account for this Mesozoic area to the north.

Taking first the section at the boundary, Section B, Figure 2, illustrates an early stage in the compression of the region. In this, as in subsequent sections, the shortening shown is qualitative, as no attempt has been made to estimate the actual shortening (which may have been considerable) of the region involved in the folding and overthrusting. These early stresses are supposed to have compressed the beds nearer the old land and to have thrown them into low folds, leaving the eastern zones virtually unaffected except perhaps for a slight uplift. On continued compression, as illustrated in Section C, the western folds were steepened, the lower, more competent strata were raised higher, and a greater stress was transmitted to the eastern zones, the first effect of this being to gently fold the Mesozoic measures. At this stage there may have been more severe folding in the upper strata in the western zones, accompanied by overthrusting, but as these Mesozoic beds have been almost entirely removed their condition at this time is a matter of inference only. At the stage represented by Section D, the western zones were stronger by reason of thickening by folding, and because the lower more competent Palæozoic and Precambrian strata have been raised higher, so that a greater stress is transmitted to the eastern zones, in which the less competent Mesozoic strata are exposed. The effect of this stress is supposed to have caused reverse faults to develop, dipping westward at something over 30 degrees, this being the angle between the strata and the fault surfaces as previously described. The westernmost of these breaks is considered to be the largest, as it is nearest to the stress and it is shown at depth ending in an anticline in the lower strata.

Fewer breaks appear to have taken place in the boundary section than farther north, and it is possible that here the stresses were relieved by a large amount of slipping along one surface rather than lesser slipping along several breaks. Sections E and F illustrate progressive changes caused by continued compression, one effect of which is to cause steepening of the reverse faults of the eastern structural area. This steepening will be explained in connection with the North Kootenay pass section. In Section F a large displacement along the Lewis thrust is indicated, caused in part by the greater opposition to further deformation by the already deformed Mesozoic strata to the east. At the stage of Section F, representing the end of the compression of the Laramide revolution, the western structural area was still high, and not greatly deformed. The strata were disposed in moderate folds, for there is no evidence of generally severe folding in the rocks of the MacDonald and Galton ranges (12,n). There may be an exception to this general moderate folding in the case of the structures near the present Flathead and Kootenay valleys. Daly maps limestone fault blocks, presumably of Palæozoic age, in these valleys (12,n) and there are downfaulted blocks of Mesozoic rocks in the Flathead valley north of the boundary (26), (32). The structure is, therefore, more complex in detail than the sections show.

The effects of the final major event in the structural history is shown in Section G, which illustrates diagrammatically the present conditions near the 49th parallel. Consequent on the relaxation following the compression of the Laramide revolution the western arched zones collapsed along a series of normal faults, some of which have been mapped by Daly. The easternmost fault, that along the east wall of the Flathead valley, was one of the greatest of these breaks, and dropped the block under the Flathead valley in such a way as to cause ponding of the consequent stream that occupied the depression, and in these shallow freshwater basins, the Tertiary Kishenena formation was deposited. That the episode of relaxation accompanied by normal faulting continued into the Tertiary is shown by the tilting of these Tertiary sediments in a constant eastward direction (45,d), (26,c). The integrity of the major syncline of the Clarke range may be explained as being caused by the thickening and strengthening of this central structural area by folding and overthrusting.

The structure at the North Kootenay pass section, illustrated in Figure 3, is different in certain respects. For example, Mesozoic rocks here occupy the surface of the western structural area; the central structural area is narrow, and there are many more reverse faults in the eastern structural area. The development of the present structure is shown by the successive sections. The significant process illustrated is the development of "soles" from some of the reverse faults in a manner analogous to that indicated in Cadell's experiments (20,b). The development of these soles furnishes the key to the explanation of the present steep attitude of the reverse faults of the region. The slices of the earth's crust above these "soles" are supposed to have rotated so that the faults and the strata were given westward dips steeper than those caused by the compression alone. This is the explanation of the rotation observed in the southern sections of Rose's map of the Blairmore area, which has been previously referred to in this paper (39). The steepening of the "soles" as they reach the surface is in accordance with the experimental results of Quirke (30) and of Chamberlin and Miller (10). The last section shows the effects caused by normal faulting consequent on the relaxation of the compressive stresses of the Laramide revolution.

I realize that an explanation of the complex structural relations of the Rocky mountains can only be of the most tentative sort until our knowledge of the field relations of the region, and our knowledge of theoretical and experimental geological mechanics is more nearly complete. The explanation attempted in this paper will be of value, however, if only to direct attention to a region where scenery, accessibility, very well-exposed rocks, structures visible in three dimensions, and a delightful summer climate combine to make this district one that will richly reward a careful structural study.

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Pleistocene Interglacial Deposits in the Vancouver Region, British Columbia.[1]

By EDWARD W. BERRY[2] and W. A. JOHNSTON, M.A., B.Sc., F.R.S.C.

(Read May Meeting, 1922)

INTRODUCTION

Two Pleistocene till sheets or boulder clays separated by stratified sands and gravels have long been known to occur in the Vancouver region, British Columbia.[3] These stratified sands and gravels and similar deposits in the state of Washington have been generally regarded as glacial outwash deposits, formed during a period of recession of the ice. Some geologists[4] have held that the stratified deposits indicate merely a temporary recession of the ice, but others[5] have pointed out that the evidence of weathering and erosion of the stratified deposits and lower till, previously to the deposition of the upper till, indicates an interglacial period of long duration. There has been published up to the present, however, practically no evidence regarding climatic conditions during the supposed interglacial period which would indicate whether the recession of the ice-sheet in this general region was extensive, or was merely temporary.

A small collection of fossil plants was made by the junior author in September, 1921, from unconsolidated sandy and silty beds exposed in the sea-cliff at Point Grey, near Vancouver, British Columbia. The beds are apparently interglacial in age, and the plant remains furnish some definite evidence regarding climatic conditions during the time of deposition of the beds. In the present paper the mode of occurrence and character of the beds are described by the junior author and the character and significance of the fossil plants by the senior author.

THE PLEISTOCENE DEPOSITS

Good sections of the Pleistocene deposits in the Vancouver region are exposed in sea-cliffs of Point Grey peninsula. The peninsula

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[3]G. M. Dawson, Geol. Surv. Canada, Ann. Rep., Vol. VII, 1894, p. 253B.

[4]O. E. LeRoy, Geol. Surv. Canada, Publication 996, 1908, p. 27.

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extends about four miles into the strait of Georgia and is bounded on the north by English bay, on which a part of the city of Vancouver is situated, and on the south by the recent delta of Fraser river. It is about 4 miles across at its inner end, and about $1\frac{1}{2}$ miles near its outer end. It is fairly flat topped and is for the most part about 300 feet above the sea. Sea-cliffs 100 to over 200 feet high border it on the northwest, west, and southwest sides. The cliffs are highest near the west end of the peninsula and are cut in unconsolidated deposits, which apparently form nearly the whole peninsula, for the only bedrock outcrops are on the north side near the inner end, and are only a few feet above sea-level.

Good sections of the unconsolidated deposits are exposed at several places in the face of the sea-cliffs. The upper part of the sections in most places is typical boulder clay or till which is usually only 6 to 10 feet thick, but thickens towards the inner end of the peninsula, and at one place on the north side fills an erosion hollow in the underlying stratified deposits and extends down to sea-level. The stratified deposits underlying the boulder clay vary in thickness from a few feet to nearly 200 feet. The upper and greater part of the stratified deposits consists of sands and gravels and some silt. These materials are in part cross-bedded, and in part horizontally bedded. They are unweathered and without fossils, and are probably glacial outwash.

The outwash sands are underlain by horizontally bedded sands and silts containing plant remains and peat beds. These beds are here referred to as the Point Grey formation (See Plate I). Their upper surface is about 50 feet above high tide level and their lower surface, where exposed, is 6 to 10 feet. They consist of alternating sand, silt, and peat beds. The sand is partly horizontally bedded and partly cross-bedded, the beds being somewhat thicker than the silt beds. The lowest bed is a yellowish silt, and was found at several places, on the north and west sides of the peninsula, to contain numerous poorly preserved leaf impressions. The peat beds occur chiefly in the face of the cliff near the end of the peninsula, 100 yards north of an old pier. They are three in number and are 2 to 5 inches thick. They occur in the upper part of the series and are underlain by deeply weathered and leached silt beds without definite stratification. The peat is compacted and weathers out in relief; water-worn fragments of it are scattered along the coast. The series passes upwards without definite break into the overlying fluvioglacial deposits and its upper surface is nearly at the same level on the northwest, west, and southwest sides of the peninsula. It is underlain by cross-bedded sands and gravels which extend down to sea-level. The sands are mostly unoxidized and contain in places pebbles up to 3 or 4 inches in diameter. They are probably glacial outwash deposits.

The plant-bearing beds are clearly alluvial plain deposits and because of their isolated occurrence, on a point projecting into the strait of Georgia, must have been formerly more extensive than at present. They show that during the time of their formation, the position of sea-level relatively to the land in this area, was about the same as at present, or was lower. The plant remains are of special interest because the beds in which they occur are in place, and the plants must have lived nearly in the locality in which their remains are now found.

Although the plant-bearing beds are not seen to be directly underlain by glacial till—and, therefore, their interglacial age is not definitely proved—they are overlain by thick deposits of boulder clay and glacial outwash, and are believed to be Pleistocene, interglacial beds for the following reasons. Two boulder clays separated by stratified sands, gravels, and clays are shown in sections exposed along Burrard inlet near Burrard Lumber Company's mills, in the cut bank of the Fraser southwest of New Westminster, in the sea-cliffs near Whiterock, and at other places in the general region. In most of these sections, the stratified sands and gravels are apparently glacial outwash, and the stratified clays are mostly laminated clays probably formed in fairly deep water, and are unfossiliferous. The upper part of the clays, however, is in places weathered, for example at Whiterock, and masses of it are included in the upper till. The contact of the till with the stratified deposits is markedly irregular, indicating that the upper till rests on a weathered and eroded surface of the stratified deposits. The plant-bearing beds may represent land deposits formed during this period of erosion. The beds are unconsolidated, and are nearly horizontal, whereas the known Tertiary beds in the region are at least partly consolidated, and are tilted. It is known from borings that the Pleistocene and Recent deposits in the delta of the Fraser extend in places to depths of over 1,000 feet below sea-level, and that, therefore, the land probably stood considerably higher above sea-level in preglacial time than at present. The material composing the silty beds resembles glacial silt except that it is deeply weathered and leached, and the beds are underlain by sands and gravels which are similar to the known glacial outwash deposits of the region. There is a transition upwards from the unfossiliferous outwash sands at the base to the fossiliferous beds, and also from the fossiliferous beds to the overlying glacial deposits, apparently indicating gradual changes in climate from cold to warm and again from warm to cold conditions. The fact that the plants have a very modern character as pointed out by the senior author also shows that they are post Tertiary.

The thickness of the beds—about 40 feet—and the fact that the region was in part forested during the time of deposition of the beds show that the time interval must have been of considerable length, and that an extensive retreat of the ice-sheet must have taken place.

Fossil Plants from the Point Grey Formation

The plants which it has been possible to name are *Salix Barclayi* Anders, *Salix myrtilloides* Linné, *Chamaedaphne calyculata* (Linné) Moench, *Kalmia glauca* Ait., and *Vaccinium ovalifolium* J. E. Smith. In addition to these five still existing species that can be definitely recognized, the collection contains fruits of a Populus, leaves of Arctostaphylos, fragments of the leaves of grasses or sedges, and a considerable number of lignified branches, as well as fragments of leaves that are not determinable.

None of the foregoing plants are characteristic of the modern Arctic, Tundra, or so-called Barren Ground flora. Not only is this conclusion negatived by the species identified, but the presence of the fruits of a Populus, and the branches of trees also indicate that this general region was forested at the time that the plant-bearing beds were deposited. The existing Sub-Arctic forest region, or what is sometimes called the Arctic forested area of North America, has a somewhat indefinite southern boundary, which, in general, coincides with the southern limit of the great coniferous forest that stretches across the continent from Alaska to Labrador and Newfoundland.

There are no traces of conifers among the fossils, although such negative evidence may be considered as worthless. None of the forms specifically identified are characteristic of the Sub-Arctic forest zone except *Salix Barclayi*, and there is some uncertainty regarding its identity. Although *Salix myrtilloides*, *Kalmia glauca*, and *Chamaedaphne calyculata* all occur in bogs in the Sub-Arctic zone, they are more typical of similar environments in the Temperate Zone. Beyond this, comparisons cannot profitably be made with the existing phytogeographic areas. For example, the region including Point Grey now forms part of an area known as the Columbian region, characterized by dense forests, a heavy rainfall, and a definitely recognizable assemblage of plants. That the rainfall of this region, after the

Cascade uplift, was much the same as it is at the present time can scarcely be doubted, but the fossils collected do not represent a sufficiently varied assemblage to make reliable conclusions possible.

It will be seen from the ranges given under the species enumerated below that some of these extend southward as far as New Jersey, Georgia, Illinois, Iowa, Colorado, and California, and that they are properly considered as temperate types. The presence of a willow, identified as *Salix Barclayi*, is more than offset by the southern ranges just alluded to, and by the presence of an Arctostaphylos, which, as near as I can determine, is closest to the Sonoran species *Arctostaphylos manzanita* Parry.

The fossil plants are clearly indicative of a bog, moor, or heath environment, but that the region was in general forested and trees were near at hand is shown by the lignified branches and Populus fruits already mentioned, and by *Vaccinium ovalifolium* which is a shady forest shrub rather than a bog plant. Although it is impossible to arrive at perfectly conclusive results in dealing with so small an assemblage, there is nothing in the plants described that in my judgment warrants considering that the climate was especially different from what it is at the present time in this part of British Columbia.

It is to be expected that fossils of such recent geological times shall be largely, if not exclusively, of still existing species, as are those of the Point Grey deposits. The fact that some differences in range as compared with existing ranges are shown by *Salix Barclayi* and the *Arctostaphylos* warrants considering the deposit as of late Pleistocene age, and the character of the plants suggests that they were contemporaneous with the last interglacial period, or, still more probably, that they flourished during one of those climatic oscillations corresponding to those of post Wisconsin or post Würm time. The latter have been worked out with great precision for the Alps by Penck, and for the Scandinavian ice-sheet by De Geer and his collaborators. The recent studies by De Geer and his assistants in New York and New England have suggested that the major climatic history of late glacial time was a general and not a local affair. I would, therefore, be inclined to think that the fossil plants found at Point Grey represent a warm interval in late glacial time, probably subsequent to the maximum advance of the Wisconsin ice-sheet of the northeastern part of North America. The species identified from the Point Grey deposit are briefly commented upon in the following notes:

Order Salicales

Family Salicaceae

Salix Barclayi Anders (?)

Fig. 10

There is some uncertainty regarding the identification of this species, the recent leaves of which are often relatively more elongated. The resemblance is close, however, and the leaves are somewhat variable. My recent material was from Kodiak island, and the existing form is a low shrub, typical of northwestern Arctic America, which is an additional reason for doubting the identity of the fossil, since all of its associates are temperate types.

Salix myrtilloides Linné

Figs. 1-5

The leaves of the bog willow are the most abundant fossils in the collection from Point Grey, and are positively determined. Figure 4 I regard as a very small leaf of this species since the venation is of the same type as in the larger leaves. In the existing flora this species is a low shrub from 1 to 3 feet tall, growing in bogs from New Brunswick to British Columbia and ranging southward to New Jersey along the Atlantic coast, and to Iowa in the Interior. I do not know its southern limit on the Pacific coast, but it is not uncommon in similar situations throughout western Washington.

Populus sp.

Capsules, unquestionably those of a Populus, are present in the Point Grey deposit. They appear to be most similar to those of the existing *Populus acuminata* Rydberg, a stream bank cottonwood of the eastern Rocky Mountain foothills from Assiniboia to Colorado. Their specific identity is uncertain, however, and they may represent some other Populus, their chief significance being the proof they offer of a forested country.

Order Ericales

Family Ericaceae

Arctostaphylos sp.

Fig. 6

This coriaceous ovate leaf is typical of a number of the larger leafed and erect shrubby species of this genus which is so abundant in the existing flora of the western part of North America. The fossil appears to be most like the modern *Arctostaphylos manzanita* Parry, a chaparral shrub of the Coast ranges of California and a member of the flora of the Upper Sonoran Zone.

Kalmia glauca Ait

Fig. 7

The modern form is a low shrub of the humid transition zone of the Columbian region, and grows in bogs from Alaska to Labrador, and southward to New Jersey on the Atlantic coast; to Michigan and Colorado in the Interior; and along the Sierra Nevada to California on the Pacific coast.

Chamaedaphne calyculata (Linné) Moench

Fig. 8

These fossil leaves were coriaceous with revolute margins. In the existing flora the species is a shrub, 2 to 4 feet tall, an inhabitant of bogs and swamps from Newfoundland to Alaska, and ranging southward to the mountains of Georgia in the east; to Illinois and Michigan in the Interior; and to British Columbia on the Pacific coast.

Vaccinium ovalifolium J. E. Smith

Fig. 9

The modern form is a shrub, from 3 to 12 feet tall, of shaded woodlands. It occurs from Quebec to Michigan, Oregon, and Alaska, and is also found in Japan. This range suggests that the species is one of considerable antiquity, since the present day means of dispersal would not permit the exchange of Temperate Zone forms between Asia and North America.

Explanation of Plates

Plate I

Section of Pleistocene deposits, in sea-cliff at Point Grey, near Vancouver, B.C. The lower, darker-coloured beds are plant bearing. The cliff is about 200 feet high.

Plate II

Figures 1-5. *Salix myrtilloides* Linné. Figure 4. A small leaf. Figure 5, Enlargement of preceding to show venation.

Figure 6. *Arctostaphylos* sp.

Figure 7. *Kalmia glauca* Ait.

Figure 8. *Chamaedaphne calyculata* (Linné) Moench.

Figure 9. *Vaccinium ovalifolium* J. E. Smith.

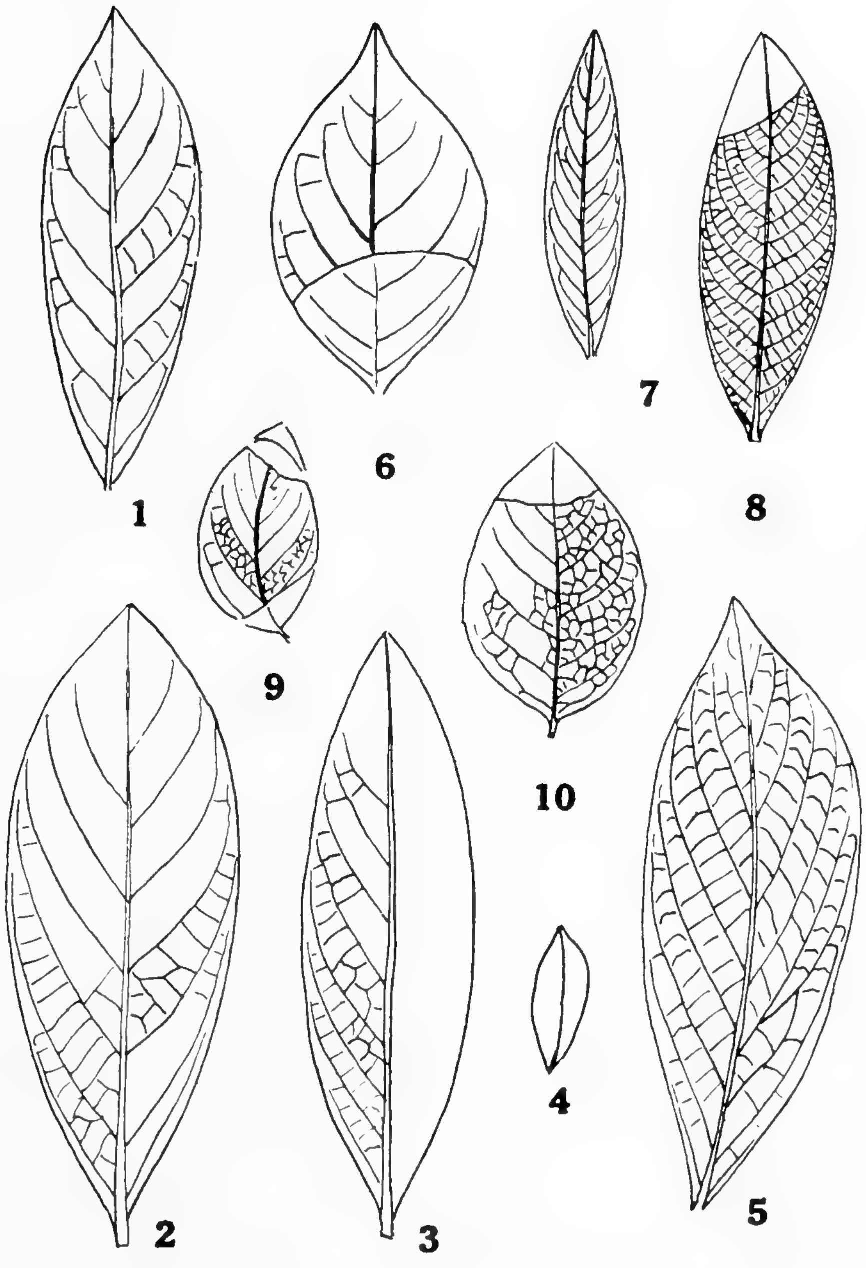
Figure 10. *Salix Barclayi* Anders (?)

All from the late Pleistocene of Point Grey, near Vancouver, B.C.

PLATE I

Pleistocene deposits in sea-cliff at Point Grey, near Vancouver, B.C.

PLATE II



Bottom Deposits of McKay Lake, Ottawa[1]

By E. J. WHITTAKER, M.A.

Presented by E. M. KINDLE, A.B., M.S., PH.D., F.R.S.C.

(Read May Meeting, 1922)

INTRODUCTION

The writer was engaged during a part of the field seasons of 1916 and 1917 in a comparative study of the fossil fauna of the marl deposits of McKay Lake, near Rockcliffe, Ottawa, and the present fauna of the lake. The results of this investigation were published in the *Ottawa Naturalist.*[2] While dredging to ascertain the fauna in the lake at the present time, a peculiar red ooze was discovered in the deeper parts of the lake, which showed remarkable lamination and was very unlike the more common freshwater sediments. This was of sufficient interest to warrant study into the bottom deposits of the lake as a whole, and this paper is the result.

McKay or Hemlock Lake in Rockcliffe, Ottawa (see Plate I, A), is well known and readily accessible to all Ottawans, and during the war became more familiar than usual to many as it lay on the route to the soldiers' camp and rifle ranges. It is a small body of water only about 500 yards long and having a greatest breadth of about 200 yards. One-eighth of the total water area is occupied by a bay, the bay indenting the eastern shore to a depth of about 150 yards. Its greatest depth is only about thirty feet, although it is difficult to determine the exact point at which the sounding lead hits bottom, owing to the oozy character of the latter in the deepest parts. The history of this basin dates back to the end of the Pleistocene when the land emerged from the Champlain Sea. Topographically the lake has two distinct types of shoreline. On the west side where bed rock of Chazy age is exposed, the shores are high, low ramparts of sandstone outcrop and peaty or mucky deposits are absent. Elsewhere the lake is surrounded by beds of marine sands and clays, and here the shores are low and owing to the considerable quantity of mucky and peaty deposits can scarcely be approached on foot except at the

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[1]Published by permission of the Director, Geological Survey, Ottawa.

[2]Whittaker, E. J. The Relationship of the Fossil Marl Fauna of McKay Lake, Ottawa, to the Present Molluscan Fauna of the Lake. Ottawa Naturalist, Vol. XXXII, No. 1, pp. 14-19.

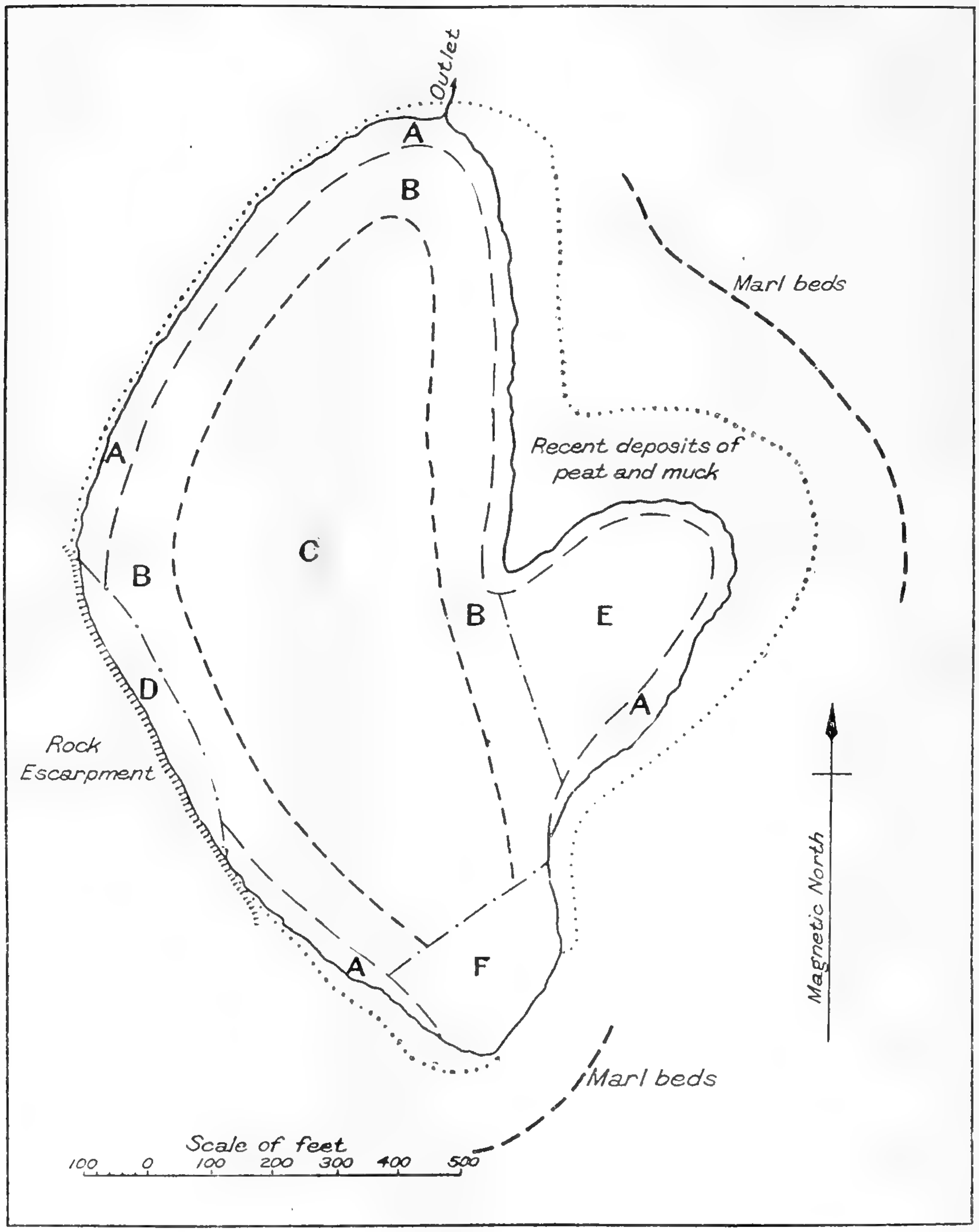

Figure 1

McKay lake, Ottawa. The bottom deposits of areas marked A are black muds; B, blackish brown mud; C, banded reddish ooze; D, coarse materials derived from cliff along the shore; E, muddy marl; F, sand.

south end where the shoreline for a short distance is composed of sand only.

A glance at the map of McKay lake shows the areas well represented. The area between the shore and the dotted line surrounding it represents mucky deposits.

As may be seen from the map, the outlet of the lake is at the extreme north end of the lake. It is a small stream two to four feet wide and about one-half a mile in length, which flows into the Ottawa River. This stream has cut a valley from twenty-five to forty feet deep and from eighty to one hundred feet wide at the top through the Champlain clays. The former level of the lake must have been nearly at the top of these deposits on the emergence of the land from the sea. Erosion by the outlet stream through the soft unconsolidated clays must have been rapid. As the level of the lake fell and the grade decreased, the erosive power of the stream diminished, and now is almost negligible. Subsequent to the withdrawal of the sea the lake has been depositing its sediment products in its own freshwater basin up to the present time.

Ancient Bottom Deposits of McKay Lake

As noted above the lake is surrounded on the north and east sides by marine clays and sands while an escarpment of rock of Chazy age borders the west side. On the south side there is a bed of marl containing freshwater shells, two to four feet in thickness, and about 15 feet above lake level. This marl represents one of the deposits of the earliest stage of McKay Lake. It rests upon sand which frequently shows crossbedding and folding with occasional boulder and gravel contents, suggesting that these underlying beds are of fluvioglacial origin. Elsewhere near the lake these fluvioglacial deposits are covered by marine clays.

These marl beds date back probably to the closing stage of marine submergence. The former McKay Lake which was much larger than at present must have remained at nearly the same high level for a period during which these marl beds were laid down. When the stream finally cut back from the Ottawa River to the outlet of the present lake, the water dropped very rapidly to its present level, eighteen feet below the top of the marl beds. As the lake was thus reduced in size it was removed from direct contact with the marine clays, and marl deposition practically ceased. Although at present occupying only a restricted area at the southern end, eighteen to twenty feet above the present lake level, they were probably of much greater extent but have subsequently been removed by erosion. The marl is fresh-looking and, where not rust stained from overlying deposits, it is yellow-white to white. A block of the material placed in water disintegrates rapidly. It consists of a large proportion of freshwater shells well preserved in a matrix of a fine powder of calcium carbonate. Only a few shells are fragmentary; for the most part they are complete.

There have been two theories advanced with regard to marl deposition. The older one assumes that the lime is precipitated chemically owing to the removal of carbon dioxide from the water. Davis, in two papers,[1] has shown that certain algae, particularly *Chara* and to a lesser degree *Zonotrichia*, play an important role in the formation of marl, the latter forming incrustations above the stems of the algae. *Chara* is present in the waters of McKay Lake at the present time, where marl deposition is very small. No evidence has been procured, however, to show that it was present in the early stages of the lake at the time the marl was deposited. The fine material shows no evidence of having formed an incrustation on plant stems, no tubes of calcium carbonate which surround the stems are to be found and no oogonia or fruit bodies of the plant are present. It must be remembered that this material was not subjected to any wave action and hence it is unlikely that such material would be completely destroyed if originally present. So it seems probable in this particular instance the marl has been largely produced by disintegration of molluscan shells and by chemical precipitation from solution.

The most probable source of the marl in this deposit would be the lime content of the marine clays which were leached out and carried into the waters of the former McKay Lake when its size was much greater than now. In some other parts of the Ottawa Valley instead of forming marl beds the lime content of the marine clays has leached down and cemented the underlying gravels. This is well shown at Tenaga, Quebec. The calcium carbonate in the marl at McKay Lake shows no tendency to work down and cement the underlying sands.

These marls are probably contemporaneous with the beds in the section on p. 150, immediately above the slaty gray clay. As in present day deposition the marl was deposited around the shore while sediments of a different nature were deposited in the deeper portions of the lake.

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[1]Davis, C. A. A Contribution to the Natural History of Marl: Jour. of Geology, Vol. VIII, 1900, pp. 485-497, and, A Second Contribution to the Natural History of Marl: Jour. of Geology, Vol. IX, pp. 491-506.

MODERN BOTTOM DEPOSITS

Field Methods

In making an examination of the bottom deposits of McKay Lake, a series of traverses 100 feet apart were made east and west, across the lake. The position of each station, fifty to one hundred feet apart, was determined by a line carried out from the shore and in such a small lake this was quite satisfactory. Where necessary stations were occupied at closer intervals. Samples of the bottom were brought to the surface by a miniature orange-peel bucket, comparable in method of operation to the large dredges. In the soft oozes the bucket often buried itself completely. A small hand dredge was used close to shore for bringing up molluscs and bottom samples. It could not be used in the softer oozes as it would bury itself and fill up completely, rendering it impossible to pull on board. The orange-peel bucket, however, worked very satisfactorily, and very little material washed out as it reached the surface.

Description of Deposits

The lake, though small, has several well defined types of bottom deposits with a corresponding difference in fauna in different parts of the lake. As can be seen from the map, the shore for a distance of about four hundred feet on the west side of the lake is composed of walls of sandstone and shaly limestone, either as low cliffs four to six feet high, or sloping back at a more gentle slope. The rock extends outward under the water opposite the rock wall for a short distance, twelve to fifteen feet, but beyond that is covered by recent deposits. These consist of rock fragments and a certain amount of mud and sand. All of these have been derived from the rock wall and above with the exception of possibly some of the sand. The mud has been derived from the soil on top of the cliff. Wave and current action in the lake is negligible and hence to a large extent, except as otherwise noted, the heavier materials such as gravel, sand, rock fragments, etc., are not transported very far beyond their point of origin. In this sediment there are very few water plants and the only organic material consists of dead leaves. These upon decay turn black and as noted later on, the colour seems to be incorporated in the shells of the molluscan forms present.

To the north of the above-mentioned section of the shoreline of McKay Lake, extending quite to the outlet, there is a narrow flat between the elevated land to the west, and the lake. This flat is marshy and contains the familiar cat tails and other reeds, and along this section the bottom of the lake close to shore consists of a soft black mud supporting an abundant fauna and flora. Practically all the species of molluscs in the lake with the exception of two or three were found in this locality. Similar bottom conditions obtain down the east side between the outlet and the entrance to the bay and also for a short distance at the southwestern end of the lake. It is of interest to note that within this zone, consisting of water from zero to ten feet in depth, is confined the molluscan fauna of the lake. No living forms were found in deeper water outside this belt. At its edge also the abundant growth of water plants abruptly stops. Following along the zone toward the centre of the lake appears a belt of blackish brown mud, slightly more tenacious than the former. This belt is very irregular, being seventy to eighty feet wide in the northern end of the lake, and almost absent at the southern end, as well as in the bay to the east. No living forms of molluscs, but many dead shells, were obtained here. This area of bottom deposits lies in water ten to twenty feet in depth.

This blackish-brown mud merges into a very unusual sediment in the deeper waters of the lake. My field notes call it a reddish jelly or ooze. This reddish jelly is covered by a thin layer of very soft mud. Close examination of this red jelly shows it to be finely laminated in alternating bands of different composition. These include greyish-white laminae alternating with dark reddish bands. This material was not consolidated in the slightest degree, and was rather difficult to photograph (see Plate I, B) because, during the few seconds required for exposure, the material slumped down perceptibly. The laminae are extremely regular and horizontal for the most part and any appearance of irregularity on the plate is due to the difficulties encountered in transporting such ooze-like material to the laboratory. A sharp knife was used to prepare a surface to be photographed, and this tended to draw out the laminae very slightly. As noted, the plate is natural size.

In addition to different physical characteristics, the red and grey bands are distinct in chemical composition. The grey bands consist largely of calcium carbonate in a finely divided state like marl which completely dissolves in hydrochloric acid. The red laminae consist almost exclusively of organic material, though traces of calcium carbonate are present. On being dried, the organic material was found to burn with a large percentage of ash. It should be said that the quantities used in the above determinations were very small, owing to the mechanical difficulties involved in separating out material from adjacent laminae when these were only about a sixty-fourth inch in thickness, so as to be certain that each sample was from one layer only. This ooze was found to abound in rhizopods and diatoms but no higher forms of life were found. The maximum depth at which this red ooze was obtained is thirty-two feet, which is also the deepest point on the lake bottom.

Two other types of bottom deposit are present. At the extreme south end of the lake for a distance of about one hundred feet the shore consists of sand which has been derived from the sand beds which border the lake on the south and east. The bottom for a distance of one hundred feet from shore, which is there sand, is characterized by a sparse assemblage of plant life, as well as by the absence of many of the molluscs found elsewhere and by the presence of *Campeloma decisum*. This species was found only at this point. The eastern bay is floored by a mud-marl bottom which also produces local differences in the flora and fauna which are more sparse here. The map (see Figure 1) shows graphically the distribution as well as other shore features.

It is thus seen that in McKay Lake we have had a highly specialized type of sedimentation which owing to its small size can be studied in detail. From large lakes its sedimentation processes are distinguished by:

(1) Absence of pronounced wave action.
(2) Absence of any lake currents.
(3) Absence of large inflowing streams with their great burden of sediments.
(4). Absence of transporting agents, hence sediments where derived from land are largely deposited near shore. Uniformity of meteorological conditions. This is impossible in a large lake.
(5). Large proportion of organic deposits.

Field Studies

As the red ooze-like material had not been hitherto encountered it was felt that the acquisition of certain information with regard to sedimentation in McKay Lake at the present time might throw some light on its origin. A series of experiments were, therefore, conducted with more or less success to find out whether sedimentation in the lake was continuous or interrupted, and if the latter, its variation during different seasons of the year. The actual work undertaken is indicated below. Difficulties encountered were due mostly to the fact that a suitable technique had to be developed as the tests proceeded, and occasionally unexpected results occurred. In the winter of 1917 three sedimentation markers were set out. Holes were cut in the ice early in January. The total thickness of ice was over two feet, but this was covered by six inches of water, the result of a January thaw. Through the hole enamelled (agate) pails eight inches in diameter with straight sides were lowered. The handles had been removed and two straight pieces of wire at right angles to each other were fastened to the top of each pail. A float of varnished pine was attached by a copper line to the wires at this part of intersection. This pine float was of a size to support amply the weight of the wire, but could not support the weight of the pail in the water. The depth was first ascertained and the copper wire cut off so that its length was about three feet shorter than the depth of the water at each station. In this way the whole was lowered gently into the water so as to avoid disturbing the bottom, with the float drawn down about three feet below the surface of the water. The holes were then filled up with snow which rapidly froze in the water. All this precaution had to be taken to avoid the advances of curious and inquiring outsiders. It was, of course, absolutely essential that the markers should not be disturbed. Their position was determined by compass intersections from prominent points as well as by distances measured by a telemeter. The wire was suspended in the above manner to avoid the possibility of the thin film of sediment being washed out as the pail was drawn to the surface. When the latter was about to be lifted, the wire was passed through an opening in the centre of a tin cover of slightly greater diameter than that of the pail. On being gently lowered by means of a string, the cover fitted exactly over the top of the pail. This avoided the disturbance or loss of any material in the pail as the latter was drawn to the surface.

This unfortunately yielded entirely negative results. When the pails had been down three months they were examined but found to contain no appreciable sediment. A second inspection after the ice had gone showed that they had been removed and later two of the floats were discovered along the shore.

The following winter, 1917-18, pans of the same nature as the above were set out in the same places but with a different method of attachment. Before the ice was set in the fall, the pans were lowered and connected to shore by woven cotton rope. Small weights were attached to hold the line to the bottom, and to avoid pulling over the pail as the line was led to near shore. The end was left lying in the water at a recognizable spot. The day following the ice had completely covered the surface of the lake so that it was safe until spring. Immediately after the breakup of the ice on the 25th of April, the sedimentation pans were visited. It was found that the rope had been decomposed and while the ends were recovered several times by a boat hook, yet they immediately parted again, and in consequence the pans could not be located.

In the winter of 1919-20, additional data were secured; the same method as above was again employed except that a small covered copper wire was used which proved satisfactory. Steel wire was used in the beginning, but it was found that its resilience caused a tension on the wire close to the pan which tended ultimately to overturn it. The copper wire proved quite satisfactory.

As before it was found that no appreciable sediment was deposited during the winter months. In the spring while the ice was still solid in the middle of the lake a large amount of water always collects upon it more especially close to shore. This is derived partly from melted ice in the lake itself, but to a large extent represents drainage down from the surrounding land which does not pass off through the regular outlet of the lake. This water which comes down by many minute rills brings down a considerable quantity of fine rock fragments, clay particles, etc. This spreads out over the ice which is covered by the water. As might be expected there was a thick bed of coarse material close to shore and the finer material farther out. In all probability this material, upon the breaking up of the ice, is scattered over a very large area of the lake as the fragments of ice are moved by the winds. An analysis of the finer material shows definitely no trace of calcareous sediments. Close to shore this layer was about 1″ in thickness, gradually thinning out to an impalpable thickness, within about forty feet of the shore. It seems entirely probable that material of this nature accumulating in spring, has contributed to a considerable extent in the production of seasonal deposits throughout the lake. A pan placed in the middle of the lake examined shortly after the ice had completely broken up showed a minute but perceptible trace of sediment, approximately $\frac{1}{2}$ millimetre in thickness. This showed only a minute trace of lime.

A sample of this mud which had come down upon the ice was kept in the office in a loosely closed jar covered with water. In the course of two months a layer of reddish brown flocculent material appeared upon the surface of the mud. This layer was about 2 mm. thick. Upon examination with a microscope it was found to consist entirely of algae. This suggested a resemblance to the jelly-like material in the deeper part of the lake. During this last summer these pans were out in the middle of the lake, and on being examined this fall in the beginning of September one could not be located, but one in the middle of the lake was found. There was no direct sediment in this, but the bottom and sides were covered with a thin dark slimy film of organic material and in the pail was a decomposed leaf, quite black in colour. Neither film nor leaf reacted with acid. It is hoped that additional pans will give further information.

In the winter of 1920-21 an albatross sampler was taken out to the lake and three cores of the bottom were obtained measuring from 37 to 50 inches in length. These samples were taken out in the middle of the lake where the red ooze was present. The very soft material was compressed considerably in the tube as measurements taken on the position of the upper ring of the sampler and at the same time on the bottom itself showed that the sampler had penetrated over ten feet. In sample No. 3 the sampler penetrated 10′ 6″ and the length of the core was 4′ 10″. Thus the volume of the ooze was reduced by over half. The section obtained is as follows. (See Plate II, Fig. B.)

Top

(*a*)	Dark grey ooze with a thin band of white marl material...	1¼″
(*b*)	Chocolate brown ooze laminated with thin layers of marl .	9½″
(*c*)	Greenish olive to deep greyish olive ooze laminae present but irregular..	19½″
(*d*)	Fuscous to fuscous black ooze, laminae present but inconspicuous..	8″
(*e*)	Slate grey clay similar to ordinary marine clay............	2″

Each sample went down to this lower slaty grey clay.

A microscopical examination showed that the whole of the material with the exception of the lower clay was practically composed of organic material except for the grey laminae of layer *b*, which has been described in detail above (See p. 150). The plants consist of algae of various types, while diatoms (some with very beautiful ornamentation) were present from the first layers above the marine clay to the very top of the sediment. These diatoms have not yet been studied. From a superficial examination many at least seem to range throughout the whole section. Scattered rarely in the beds are spicules of sponges.

Bed *d* shows laminae too fine to be counted, probably less than one two-hundredths of an inch thick for about two inches above the grey clay. It was found impossible to differentiate chemically between adjacent laminae as in the chocolate red beds. When this material became dry the laminae tended to pull apart and render themselves more apparent.

The olive green ooze of bed *c* was of much softer composition than either those above or below. The laminae are hard to differentiate though a double layer of calcium carbonate about 15¼ inches above the base of the sections is readily distinguished by contrast with the rest of the section. This is shown in the photo of the section, Plate II, Fig. B, at point marked M.

The chocolate brown ooze with its alternating grey and chocolate laminae is most interesting of all. In this band alone was it possible to actually count the laminae with a fair degree of accuracy and by actual count there are about 440 double laminae (one grey and one chocolate lamina). In Plate II, Fig. A, representing this material, the pins are separated from each other by 100 double laminae. Measurements of the thickness of these laminae over the whole thickness of these bands gave an average thickness for a double lamina of .017″. Hence each grey or chocolate band would average only .008″ or less than one one-hundredth of an inch. This thickness is, of course, in the compressed sediments. Above these laminae are some beds of ooze which are not differentiated into laminae. The uppermost ooze, zone *a*, consists of very soft material. In some of the samples it is quite black and tenuous with a thin layer of calcareous material in it. This layer owing to its lack of body is very difficult to secure and though in some samples it seems almost absent and in others as much as two inches thick, it is probably a fairly uniform band which is lost in some cases while being removed from the water.

In the section photographed all the laminae instead of being perfectly level were pulled down on one side. This was due to one side of the cutting edge of the sampler being rougher than the other and this consequently bruised and compressed the ooze causing that side to drag as it was pushed up the sampler tube. It is the same friction between the side of the tube and oozes that causes them to be compressed to such a great extent.

It is thus seen that the above core from the bottom of McKay Lake, excluding certain marly layers, is largely an ecological succession. When algae and diatoms only are contributing to deposition in the centre of the lake the yearly deposit is rather small. For even if lime were deposited it would redissolve owing to the large quantity of carbon dioxide present. The fact that in this lake the epidermis of the valves of the thick shelled unionidae, from which the calcium carbonate has been completely removed, remains, shows this to be a probability.

The marine clay did not suffer any compression in the samples taken, hence in sample No. 3 the total depth of ooze which lies upon it equals approximately ten feet. In all probability this represents the total deposition in this lake since the retreat of the Champlain sea. If the hypothesis that a pair of laminae in the chocolate brown ooze represents a year of time be correct, then the 9½″ of compressed sediment of that type (=2⅓ feet of uncompressed sediment) represents about 500 years of time only. As nearly as can be judged the other laminae, where they can be differentiated are much thinner, possibly one two-hundredths of an inch (compressed), but even that would represent at a maximum of the thickness of *c* and *d* in the section quoted 27½″ or about 5,400 years. In most estimates of post-glacial time the period is placed as much higher, from 12,000-15,000 years. It is very unfortunate that the laminae cannot be counted. It has been suggested that the slaty-grey clay at the base of the section does not represent the Pleistocene marine clay period, but that it was formed by erosion of the soft marine clays near by, and subsequent deposition in the lake. Thus these beds might be considerably younger than the ordinary marine clays. But no freshwater organic material, which would be the only proof of this, was obtained. In any case only a portion of post-glacial time is here represented. The probability is that the total thickness of freshwater sediment since the lake was formed, exclusive of calcareous material, is present in this section.

With a view to instituting comparisons in sedimentations, several sections were taken with the Albatross sampler at Fairy Lake, north of Hull. These were taken in a deep part of the lake at a depth of about 60′. Conditions here were quite different from those at McKay Lake. The sediment here consisted largely of heavy stiff clays bluish grey in colour. On examining it with a microscope it was found to be largely inorganic and contained only a small amount of organic material, diatoms, etc. This sediment has been largely derived from the cliffs in the immediate vicinity, and its quantity is much greater than that of any organic deposit.

The abrupt change from the olive-green zone *c* and the chocolate brown zone *b* and the latter and the blackish ooze at the top of the McKay Lake section is worthy of note. It is possible that a change in climate with consequent variation in organic life may have produced this contrast. When the lake was being lowered by rapid erosion of its outlet new conditions arose and if lowered very suddenly as by a flood cutting through the marine clay the same result would occur. A shoaling of fifteen or twenty feet would cause a considerable change in the character of the plant life and consequently in the nature and rate of deposition of the bottom deposits. Had a similar change in sediment occurred in Fairy Lake the climatic factor would be strongly upheld, but as noted above conditions in the two lakes are different.

In spite of the meagre information obtained it would appear that the chocolate red beds deposits are seasonal and that the pair of one chocolate brown and one grey layer represent a year. The grey layer represents the spring sedimentation when the waters which ordinarily slip into the lake come down by many miniature torrents bringing down considerable material from the marl beds above. A bed of organic material has been formed in the summer and fall from algae growth on the bottom as well as organic dust detritus such as pine pollen and decomposed leaves. It must be remembered that man has changed the character of the shoreline and in such a small lake has been able to affect its sediments. In utilizing the underlying sands the marl has been removed so that now it occupies only a fraction of its former area, so that now the lime content of the spring deposit is almost negligible. By clearing away a large part of the coniferous forest the organic content of the sediment has also been lessened. Anyone who has seen the pollen covering upon one of our northern Ontario lakes in June or July can realize what an important contribution is made by it to bottom deposits.

Influence of Bathymetric Range and Bottom Environment Upon the Molluscan Fauna

While the influence of the bottom and depth upon the molluscan fauna was not one of the primary objects of this investigation attention was given to it in a quantitative way when possible. The best work done of this nature on freshwater lake faunas is that of Dr. F. C. Baker on Oneida Lake.[1] In a very general way it may be said that there is a certain zone of maximum productivity in shallow water a short distance from shore, while in the deepest parts of the lake no living molluscs were obtained at all. In general it may be said that the fauna and flora occupied the same area. In McKay Lake no plants live in water over ten to twelve feet deep, and no animals were found beyond that limit except some insect larvae. The bottom as noted previously may be divided into:

[1]F. C. Baker. The Productivity of Invertebrate Fish Food on the Bottom of Oneida Lake, with special reference to Molluscs. Technical Publication No. 9 of the New York State College of Forestry at Syracuse University, 1918.

1.	Marshy bottom	0 - 1′
2.	Soft mud bottom depth	1′ - 6′
3.	Rock debris " "	1′ - 4′
4.	Blackish brown mud bottom	10′ - 20′
5.	Red ooze " "	20′ - 32′
6.	Sandy " "	0′ - 6′
7.	Marly " "	0′ - 6′

In zone 1 where the plant life floating and almost submerged fills the whole of the water, there is to be found *Lymnaea stagnalis appressa* floating on top in considerable numbers. It is a thin large shelled form which cannot stand exposure, and is found only in well protected places. Here also is to be found *Pseudosuccinea columella* and *Ancylus rivularis*. Occasional *Valvata* is to be found also. The small number of species and individuals in such a habitat seems to follow the general rule that where plants have captured too much of a great water area, molluscs are rare. Where plants are quite abundant but the water is in motion, a considerable number of molluscs may be present. Where the plants are moderate in number and the bottom covered with some organic debris the molluscs are at their best.

Zone 2 furnished the greatest number of specimens and species of any habitat in the lake. Here were found every species listed with the exception of *Campeloma decisum, Lymnaea stagnalis appressa,* and *Pseudosuccinea columella*. Here there is a moderate amount of vegetation, few algae, but many fresh pond lilies. The smaller forms were attached to the stems in many cases while *Planorbis campanulatus* and *Physa heterostropha* were attached either to the upper or lower sides of the pads. *Planorbis parvus* was also frequently found on the leaves. *P. exacuous* and *P. antrosus* were brought up mostly in dredging from the bottom. *P. trivolvis* was usually attached to submerged or floating logs. The pond lilies and allied plants serve as support, shelter, and food for the above forms. *Physa* especially was seen feeding upon the leaves. The larger bivalves such as *Lampsilis radiata* and *Anodonta fragilis* were observed in this habitat but near the outlet where there was a perceptible current. On the mud and debris at the bottom *Valvata tricarinata, Amnicola porata,* and the small forms of *Pisidium* and *Sphaerium* occur in great abundance, all showing the natural shade of their epidermis.

Zone 3 is a specialized habitat on the west side of the lake at the foot of the rock cliffs already mentioned. Here every spring a considerable amount of clay and rock debris are washed into the water, forming a sort of miniature delta. During the summer some of the molluscs inhabit this area. As might be expected plants are few as the influx of new material each year tends to stifle and kill off the old ones. Here *Valvata tricarinata*, *Amnicola porata*, and *Pisidium abditum* are the only forms regularly present. *Ancylus* was noted once on a dead *Physa* shell and *Planorbis campanulatus* and *P. bicarinatus* were rarely found but apparently were casual forms which had wandered in from the preceding habitat. An interesting feature about the former species was the manner in which they had by living on the dark clay and rock fragments, incorporated the colours of these materials into their shells. The epidermis of *Valvata* and *Amnicola* in the preceding habitat is a delicate or pronounced shade of green, here it is black. The colour does not seem to be merely in an external coating, but extends deep into the shell.

In the blackish brown mud of zone 4 practically all molluscan life had ceased. There were dead shells in abundance, and most of the large shelled *Lampsilis*, and *Anodonta*. A single individual of *Lampsilis radiatus* was found dead but in a natural position as though it had died there. It was brought up in a haul of the orange-peel bucket. Plant life except of microscopic forms was absent.

In zone 5—the red ooze—very rarely a shell of *Lampsilis radiatus* was brought up. In each case the shell was badly decomposed. The lime was dissolved, leaving behind the thin flexible chitinous epidermis.

In zone 6, a restricted area at the southern end of the lake, there is a sparse plant growth upon a sandy bottom. Here *Campeloma decisum*, *Planorbis antrosus*, and *Lymnaea stagnalis appressa* were found, in considerable numbers. This is the only place in the shore where there is a sand beach and since it is subjected to the small amount of wave action in the lake, many hundreds of dead shells are piled up at the water's edge. In the east bay where the bottom consists of a substratum of marl, few plants are present and the molluscan fauna is rare, consisting almost entirely of *Amnicola porata* and *Valvata tricarinata*.

In passing it may be said that for the most part, owing to the manner in which the recent deposits have encroached upon the lake, there is practically no bottom area exposed between water level and 1′ in depth, as the clumps of grass sedge and peat go down vertically to a depth of a foot or more. In many lakes important differentiations can be made in the fauna for this zone of 0 - 1′ but this zone cannot be distinguished here.

The fauna as a whole is restricted in species. This is due to the pond-like character of the whole lake, the lack of a sand mud bottom most favourable to many molluscs, and lack of wave action to aerate the water. However, as previously noted, the present fauna is more diverse than that of the ancient marl fauna.[1]

[1]Whittaker, E. J. The Relationship of the Fossil Marl Fauna of McKay Lake, Ottawa, to the Present Molluscan Fauna of the Lake. Ottawa Naturalist, Vol. XXXII, No. 1, p. 15.

Explanation of Plates

Plate I

A.—McKay lake, showing marl bed underlain by sand and gravel in upper middle of photograph. (*Photograph by Canadian Air Board from elevation of 1,300 feet.*)

B.—Alternate chocolate brown and grey laminae from McKay lake. Uncompressed sediments. Natural size.

Plate II

A.—Section of bottom deposit, McKay lake, taken with Albatross sampler, about three-quarters natural size. Sediments compressed; chocolate brown and grey laminated ooze. Pins are separated by 100 double laminae, *i.e.*, one red and one grey laminae.

B.—Section of bottom deposit, McKay lake, taken with Albatross sampler. Section slightly desiccated.

(*a*) $1\frac{1}{4}$ inches, dark grey to black ooze with a little white marl.
(*b*) $9\frac{1}{2}$ inches, chocolate red ooze.
(*c*) $19\frac{1}{2}$ inches, greenish olive to deep greyish olive ooze.
(*d*) 8 inches, fuscous to fuscous black ooze.
(*e*) 2 inches, slate grey clay.
M. Double laminae of marly material in ooze.

PLATE I

A

B

A New Genus of Characeae and New Merostomata from the Coal Measures of Nova Scotia[1]

By W. A. BELL, PH.D.

Presented by E. M. KINDLE, A.B., M.SC., PH.D., F.R.S.C.

(Read May Meeting, 1922)

INTRODUCTION

The plants and animals that lived in Coal Measures time make a special appeal to our imagination. For the first time in geological history we have records that enable us to picture large areas of land not as barren rock masses whose nakedness we fain would cover had we but the knowledge, but as living landscapes in which broad meandering rivers gleam amidst forests that are strange indeed to modern eyes, but that rival ours in majesty of form and size, and in potential importance to mankind.

Industrial exploitation of the long buried debris of these ancient forests for their use as fuel, has been the chief aid in satisfying our curiosity about the relationships and habits of numerous individual members of the Coal Measures plant and animal societies. Finally our knowledge has become sufficiently complete to enable us to recognize a succession in time of terrestrial dynasties during the Coal Measures and to apply this wisdom to the furtherance of new exploitation for coal.

The present paper is a brief description of several forms of this ancient life from the Coal Measures of Nova Scotia, whose remains are rare. The first to be considered are minute fruit bodies of algæ-like plants that were found by Dr. A. O. Hayes in the shale roof of a five-foot seam of coal at the St. Rose mine, Inverness county. They record the earliest known occurrence of the Charophyta or stone worts—a phylum that embraces the recent *Chara*, common in fresh-water ponds, lakes, pools, and brackish water lagoons of to-day. In the same beds Dr. Hayes was fortunate enough to discover a carapace of a Schizopod crustacean, somewhat better preserved than the specimen that was collected by Sir J. W. Dawson from the Joggins. These two species come from the lower part of the Coal Measures.

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[1]Published by permission of the Director, Geological Survey, Ottawa.

The two remaining species described come from eastern Cape Breton from a higher horizon. One is the carapace of a species of Eurypterid whose near allies have been found at an equivalent horizon in Pennsylvania, and in England. The presence of Eurypterids, a rapidly declining race, in Nova Scotia, had already been indicated by the previous discovery of several fragmentary abdominal remains. The other form under consideration is an odd one of doubtful relationships, but which invites comparison with such shield bearing Merostomata as the Xiphosurids or sword-tails.

Phylum Charophyta

Genus Palaeochara

Palaeochara n. g.—Oogonium like Chara, but with six, instead of five spirally wound investing cells. Genotype *Palaeochara acadica.*

Palaeochara acadica n. sp.

Description: Oogonium subglobular to pear-shaped with hemispherical base and conical apex. Length somewhat exceeding the greatest diameter. Investing cells six in number, commencing around a smooth, circular, basal area and making one complete spiral turn to the raised conical end. Six or seven spiral ridges visible on a side view. Length 0.55 mm.; diameter 0.53 mm.; diameter of smooth basal area 0.075 mm.

Locality: St. Rose mine, Inverness county, N.S.

Horizon: Coal Measures.

Remarks: The remains of the oogonium are now preserved as iron pyrites, inferred to be a pseudomorph after calcite. Thin sections examined under reflected light clearly show the *Chara* affinities of the fossil in that the oogonial investment consists of partial infillings of former spirally wound elongate cells. The position of the former walls of these cells is revealed in section either as oblique or transverse lines of parting, and in surface view by narrow grooves on the spiral ridges. The latter appearance of the surface indicates that the original calcareous deposit grew from initial deposition against the concave inner borders of the cells as in recent *Chara.* In recent Charas the lateral walls break down as the fruit matures, so that a continuous shell of lime finally surrounds the oospore. In *Palaeochara* the lateral walls evidently persisted to a greater extent. The interior of the oogonium is now filled with infiltrated calcite. The basal circular area from which the spirals spring is a sunken pit, or foramen, and probably indicates the former position of attachment of the stalk cell.

There is seemingly also a minute open pore and narrow slits between the cells at the apical end since a specimen treated with dilute hydrochloric acid admits the acid to the interior with the consequent solution of the infiltrated calcite and ebullitions of gas through the neck. The neck, however, is wholly or partly broken off in the majority of specimens. Lengths vary from 0.5 to 0.6 mm., diameters from 0.45 to 0.55 mm.

The presence of an undoubted representative of the Characeae in the Carboniferous is of great interest in connection with the occurrence of minute spirally marked globular organisms, about 1 mm. in diameter, in association with marine fossils in Middle Devonian limestone of Ohio. These were first reported by Meek[1] in 1873 from the falls of the Ohio who assigned them with some doubt to the freshwater genus *Chara* and was of the opinion that they drifted out to sea. Williamson[2] in 1880 examined similar forms from Kelly's island, Ohio, under the impression that they might be of vegetable origin, but came to the decision that they were foraminiferal and included them in his genus *Calcisphaera* which had been created to hold somewhat similar globular forms from the Carboniferous of Wales. He named the Ohio forms *Calcisphaera robusta*. Dawson[3] a few years later, in 1883, pointed out important characters in which the American species from Kelly's island differed from Williamson's description of them. Although Dawson remarks on the superficial resemblance to *Chara* fruits he agrees with Williamson in referring them to the foraminiferae, but he assigns them to the genus *Saccamina* as *Saccamina eriana*. Knowlton[4] in 1889 redescribed the species from the Falls of Ohio and presented at length the various conflicting views held regarding its affinities. The major difficulties against the Characeous affinity are stated to be the presence of nine or ten spiral markings instead of the five in recent and known fossil Chara, the twist of the spirals in a right handed instead of a left handed direction, and finally the abundant uniform distribution of the fossil in a marine formation. In conclusion Knowlton distinguishes the Falls of Ohio form with the name *Calcisphaera lemoni*. In his review Knowlton failed to recognize the description of the Falls of Ohio species presented by Ulrich[5] three years earlier in 1886. The latter makes no mention of the Chara-like appearance of

[1]Meek, F. B., Geol. Surv., Ohio, Palæontology, Vol. I, 1873, p. 219.

[2]Williamson, W. C., Phil. Trans. Roy. Soc. Lond., Vol. 171, pt. 2, pp. 520-525.

[3]Dawson, J. W., Can. Nat., 2nd ser., Vol. X, 1883, pp. 5-8, Figure 3.

[4]Knowlton, F. H.. Amer. Jour. Sci. and Arts, Vol. 37, 1889, pp. 202-209, Figures 1-3.

[5]Ulrich, E. O., Contributions to American Palæontology, Vol. I, No. 1, Cincinnati, Ohio, 1886.

the organism and includes them in the foraminifera under a new genus *Moellerina* as *Moellerina greenei.* The number of spirals are stated to be eight or nine. Ulrich's description and figures surpass in detail and accuracy any so far presented, and after a study of the Kelly's Island species the writer is convinced that Ulrich's description is applicable also to it. One discrepancy, however, is noted. Whereas all the specimens from Kelly's island examined by the writer, and apparently those by Knowlton from the Falls of Ohio, have a right handed spiral twist to the ridges, Ulrich figures one with a left handed twist. Only nine spirals were observed by the writer in the Devonian specimens to which he had access. But the number of spirals, as evident from the discovery of *Palaeochara,* does not mitigate against a possible Characeous affinity of this fossil. A much more serious objection may be raised. A feature carefully noted by Ulrich, and confirmed by the writer for the Kelly's Island species, is the presence not of a thick single wall as interpreted by Williamson, Dawson, and Knowlton, but of two thin walls with a broad intervening space, the inner spherical cavity communicating with the exterior by tubular prolongations of the inner wall at each end. The spiral ridges are restricted to the outer wall, and are a part or ornamentation of the wall itself, so that they afford no evidence of a *Chara* construction in support of the superficial appearance.

Class Crustacea

Subclass Eucrustacea

Anthrapalaemon hillianus Dawson

1877—*Anthrapalaemon* (*Paloeocarabus*) *Hilliana,* Dawson, Geol. Mag. Dec. 2, Vol. 4, p. 56. Figure 1.

1878—*Anthrapalaemon* (*Paloeocarabus*) *Hillianus,* Dawson, Suppl. 2nd ed. Acad. Geol. p. 55. Figure 10.

Description: (Based on a flattened carapace.) Carapace barrel-shaped, subquadrangular, greatest width exceeding the length exclusive of rostrum. Anterior margin straight, furnished with three marked spines, one rostral, long and thin, triangularly keeled, and an antero-lateral spine on each side, short and stout, flattened, diverging outwards from an angle of 30°. Lateral margins conversely rounded, provided in the anterior one-third with short spines or serrations, directed forwardly. Posterior margin, grooved, concavely rounded, joining the lateral margins in bluntly acute angles.

Original curvature of carapace destroyed by pressure but a raised gastric region still indicated. The lateral margins are bordered by a depressed band which broadens towards the antero-lateral corners. Anteriorly a distinct V-shaped cervical furrow joins the two flat marginal bands and divides the carapace into two unequally sized areas. The anterior of these areas has three distinct spine-bearing ridges, a median one forming the base of the rostrum, which runs for half the distance to the cervical fold, and a pair of lateral ridges on either side, which are directed so as to converge when produced at a point near the forward end of the rostrum. These ridges abut on the cervical furrow but do not quite reach the anterior margin. The area behind the cervical furrow is marked by a very faint median keel which dies out entirely half a millimetre from the posterior border.

The surface viewed through a lens is roughly pitted, and the bases of larger spines lie on the rostrum and keels.

Dimensions: Extreme length 20 mm.; length, excluding rostrum, along median line, 13 mm.; length of rostrum projecting beyond anterior margin 5 mm.; width of rostrum at anterior margin 0.8 mm.; greatest width of carapace 17 mm.; apex of cervical furrow 7 mm. from the anterior border.

Locality: St. Rose mine, Inverness county, N.S. From roof of coal seam, associated with *Naiadites*, *Ostracoda*, and *Palaeochara acadica*.

Horizon: Coal Measures. (Lower Coal Measures?)

Remarks: Although the type specimen of *A. hillianus* is proportionally narrower than the present one, the points of agreement are too many for varietal separation. Peach[1] has pointed out that in *A. russellianus* the serrations on the lateral margins are most probably the flattened spines that were borne along the whole length of lateral keels. As a result of the doublure of the test, and flattening accompanying fossilization, the serrations may appear to be restricted to the anterior portion of the carapace. This observation promotes caution in laying stress on the number of dentations visible on the margin, stated to be five on the type specimen of *A. hillianus*. The two strong spines figured by Dawson on either side of the base of the rostrum are seen in the present specimen to consist of two short spinous keels as present also in a similar position in *A. russellianus* and other species.

Dawson pointed out the close resemblance of *A. hillianus* to *A. dubius* (Prestwich). Yet the affinity must lie nearer *A. grossarti* Salter

[1]Peach, B. N., Monograph on the Higher Crustacea, Mem. Geol. Surv. G.B. Pal. Vol. I, No. 1, pp. 31-32, pl. iv. Figures 4, 6, 1908.

when one considers the shape of the carapace, its ornamentation, the size of its marginal spines, and the faint representation of the median keel behind the cervical furrow. Woodward's figures of *A. grossarti*, unlike Salter's, show the cervical furrow quite distinctly, and a median keel precisely like that of *A. hillianus*. I retain the Nova Scotian species since it has a stronger curvature fore and aft of the lateral margins of the carapace. Thus, in the Inverness specimen, the antero-lateral angle formed by the anterior and lateral margins (neglecting the acute spine) is roughly 120° as compared with 110° in *A. grossarti*, too great a difference to be due to pressure. *A. dubius*, on the contrary, is readily distinguished by the absence of marked antero-lateral spines, the arcuate frontal margin, and the even, pronounced, strength of the median keel which runs to the posterior margin.

Class Arachnida

Subclass Merostomata

Eurypterus (*Anthraconectes*) *brasdorensis* n. sp.

Description: (Based on a single carapace.) Carapace, semi-ovate, with length nearly three-fourths the maximum breadth. The posterior margin very slightly convex backwards. Genal angles produced into short bluntly acute spines. Between the prominent reniform compound eyes there is a pair of elongate elevations which border a median depression in which lies a circular ocellar mound 1.3 mm. in diameter. This mound is situated directly in front of a line tangential to the posterior borders of the eyes and was apparently the seat of the ocelli. A second pair of elevations run obliquely from the middle of the posterior border towards the lateral margins, so that the eyes are situated in triangular, depressed areas of the test.

The surface is marked by raised scales or mucros on a finer shagreen ground. The individual outline of these scales is hemioval to hemispherical with their flat slopes facing anteriorly. In the posterior half of the shield, except in the depressed areas, the mucros are large, raised, more acutely pointed, and plainly visible to the unaided eye. Anteriorly and in the depressions, they are fine or microscopic, with much less relief. Adjacent to the lateral margins they become greatly elongated and flattened, and either border the margins in a parallel position or meet them obliquely at very acute angles. Anteriorly, the carapace is clearly folded underneath in a doublure and a faint, narrow, V-shaped ridge, situated medially close to the anterior margin, is probably due to the pressure from the ventral border of this fold. (Compare *A. kidstoni.*)

Dimensions: Greatest length 15.3 mm.; greatest width across genal angles 21.2 mm.; width across median ocellar mound 18.7 mm.; distance of median node from the posterior margin 6.4 mm.; distance of compound eyes from the posterior margin 7.5 mm.; long axis of compound eyes 3.1 mm.; short axis of compound eyes 1.5 mm.

Locality: Roof of four-foot seam, from dump derived from old slope, New Campbellton, Cape Breton.

Horizon: Upper Coal Measures or Radstockian (Upper Westphalian).

Remarks: Eurypterids are rare fossils from the Coal Measures the world over, and only some dozen species have been recorded.

The present species and an allied English Radstockian species *Glyptoscorpius kidstoni* Peach have carapaces agreeing in size, relative proportions, and ornamentation to that of *Anthraconectes mansfieldi* C. E. Hall from the Alleghany series. The resemblance is particularly close to those variants of smaller size figured by Jas. Hall as *A. stylus*. Specific identity, however, is withheld since nothing is known about the body of the Nova Scotian form. Accordingly, emphasis is placed on slight differences in outline of the carapace, distinctions that probably are inconstant and of doubtful specific value. The shield of our specimen has been so flattened by pressure that the anterior margin is covered, and accordingly it was not determined whether a short anterior spine similar to that borne by *A. mansfieldi* was present. The ornamentation of *A. brasdorensis* is identical in plan to that of *A. kidstoni*. In fact, the latter carapace differs only in its slightly greater proportional length and in the presence of a shallow indentation on the posterior border.

A carapace of an Eurypterid has not hitherto been described from the Coal Measures of Nova Scotia. Salter,[1] however, in 1863, assigned some fragments of Merostomatan abdomens to this genus, viz., *E. ? pulicaris* from the Little River group of St. John, N.B., a fragment of a large body segment comparable to *E. scouleri* Hibbert, from Port Hood, and an incomplete telson from Joggins whose resemblance to that of *Hastimima whitei* White from the Coal Measures of Brazil has been pointed out by Clarke and Ruedemann. The excellent preservation of the present carapace leads to the hope that the same horizon may yield further, and more complete, specimens of these ancient arachnids, whose race was rapidly approaching extinction.

The tendency of the Carboniferous Eurypterids to form dermal scale-like excrescences is given phylogerontic significance by Clarke and Ruedemann. Also these authors regard the subgenus *Anthraconectes* to be fresh or brackish-water inhabitants. *A. brasdorensis*

[1]Salter, Quart. Jour. Geol. Soc., Lond., vol. 19, pp. 78-79, 1863.

is associated at New Campbellton with abundant *Anthracomya* in a series of strata which present strong evidence of freshwater deposition.

Subclass Merostomata

Genus Schistaspis

Schistaspis (σχιστός cloven; ἀσπὶς shield)—Cephalic shield relatively large, hemispherical, smooth, with no distinct prominences or glabellar region. Paired median simple eyes doubtfully present near the anterior margin. Head shield articulated behind with a post-cephalic shield whose wing-like expansions are directed outwards and backwards. Abdominal free segments 8 (?) in number, non-trilobate, with spine-like posteriorly directed epimeral projections. The first seven abdominal segments are single. The last abdominal segment is anchylosed to a small hemispherical tail plate which doubtfully bore a telson spine in articulation with it.

Schistaspis bretonenis n. sp.

Description: Length, exclusive of possible telson spine, 27 mm.; maximum width 12.6 mm. Cephalic shield large, with hemispherical outer border, and concave, evenly curved posterior border. Genal angles acute but scarcely prolonged into a spine. Lateral margin with a narrow raised border which disappears, or is folded beneath, at the extreme front. Although the shield is crushed and somewhat fractured, there is no evidence of a raised glabellar region, nor could the definite presence of compound eyes be detected on the dorsal surface. Medially, however, and situated 1.1 mm. from the front margin there is a minute circular mound about 1/5 mm. in diameter which doubtfully may represent one of a pair of simple eyes. It lies a little to the left of the median line and the corresponding position to the right is obscured by a bit of matrix.

Behind the cephalic buckler and free from it, there is a crescentic shield whose anterior convex margin follows the contour of the shield in front. The lateral angles are acute but blunter than the cephalic genal angles. They lie about opposite the fourth abdominal segment. The posterior margin of this thoracic shield is triangular, the two straight edges enclosing in one specimen an angle of 116°, in the other an angle of 103°.

The first two visible abdominal segments are partly covered by overlap of the crescentic shield. The succeeding five segments are simple and free, with straight axial border in the frontal region of the abdomen but becoming arched in the posterior region. The epimeral portions of these segments are defined from the axial portions in some segments by narrow, curved longitudinal grooves. They end in acute projections. The succeeding and last segment is formed of a fusion of somites. Anteriorly on this last segment there are two free epimeral projections. A small hemispherical tail-like area is marked by a median triangular depression suggesting articulation with a caudal spine which has been lost. In one specimen the entire posterior segment is lacking.

The total length of the abdominal portion is 8 mm., the width across the 4th segment 7.5 mm. On account of the partial covering of matrix and overlapping of the posterior shield there is a false appearance of a marked contraction of the body at the first two segments.

In the more complete specimen the cephalic shield has suffered rotation to the left and on that side overlaps all but the outer corner of the hinder shield. On account of this distortion and the presence of minute slips within the test it is difficult to trace the precise limits of the two shields in the axial region. Fig. 14 is a drawing to show more clearly the relations. A portion of the headshield a_1 has been broken off and slipped under A. There is little evidence such as transverse wrinkling to indicate any important foreshortening, so that in its natural position shield A probably overlapped somewhat onto the anterior portion of shield B. A similar overlapping is apparent in the second specimen, although the margin of the fore shield is not complete. It seems evident at least that the two shields are not fused together in the axial region.

The shell substance is thin and lacks the scale-like ornamentation of the Eurypterids.

Although the general contour of the body and of the large cephalic shield resembles other Xiphosurians there is no apparent trilobation of the body and the presence of a distinct post-cephalic shield is unique. Were it not for the presence of the double shield and the absence of trilobation *Schistaspis* would be very similar to *Belinurus*, which has an abdomen of eight segments, of which the 7th and 8th are consolidated, in addition to a long, slender telson. *Euproöps* has seven abdominal segments fused together, besides a short caudal spine.

Explanation of Plate

Figs. 1, 2. *Chara*. Two specimens of a species occurring in a hot spring at Banff, Alberta. x 26.

Fig. 3. *Palaeochara acadica* n. sp. Side view x 26.

Figs. 4, 5, 6. *Palaeochara acadica* n. sp. View of basal ends of three specimens x 26.

Figs. 7, 8, 9. *Palaeochara acadica* n. sp. Longitudinal sections of three specimens viewed by reflected light. Note position of cellular walls, indicated by transverse or oblique lines of parting. Fig. 9 shows possible remnants of a diaphragm separating the neck cavity from the oospore. x 26.

Fig. 10. *Anthrapalaemon hillianus* Dawson. Dorsal view of carapace. x 2.

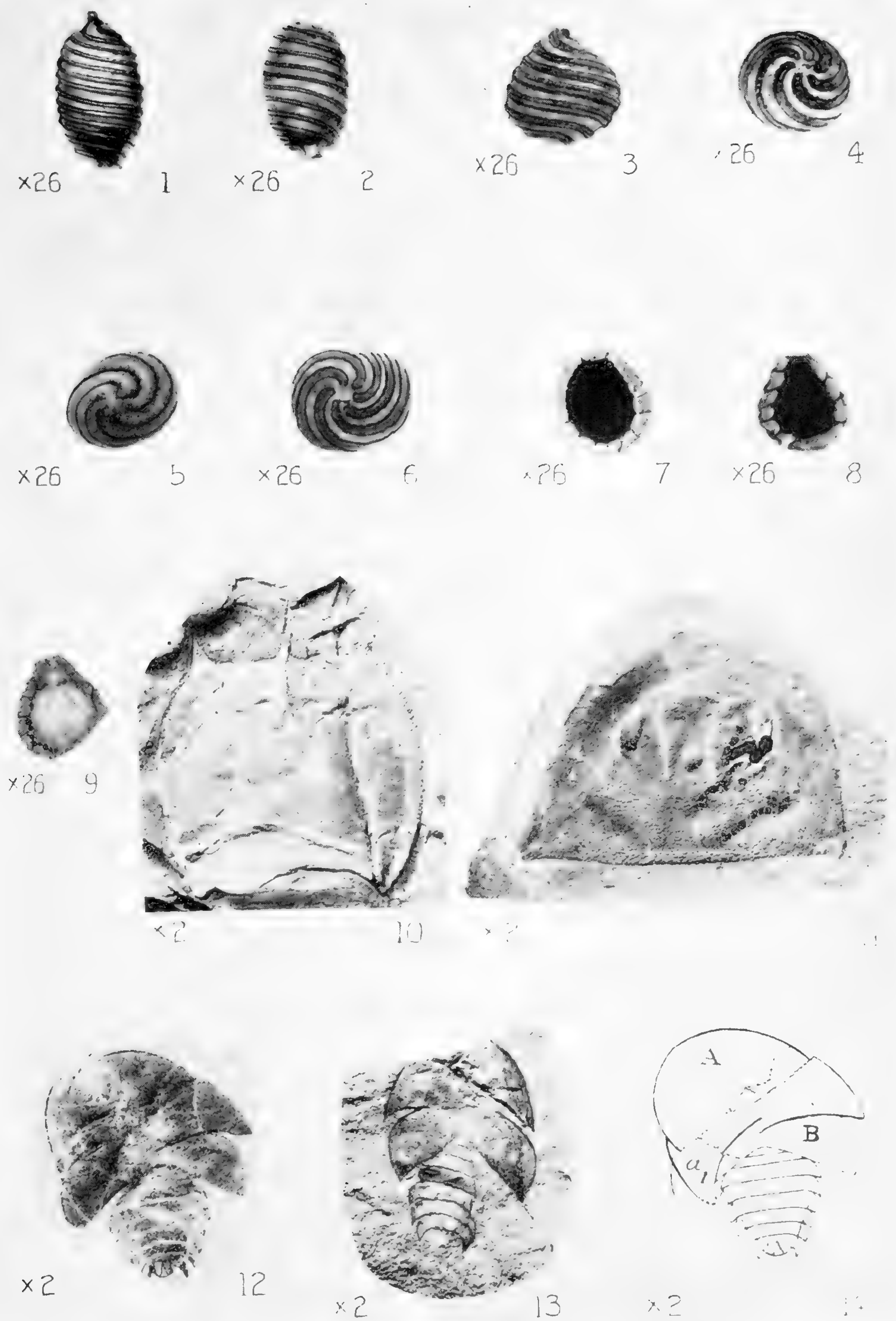
Fig. 11. *Eurypterus* (*Anthraconectes*) *brasdorensis* n. sp. Dorsal view of carapace. x 2.

Fig. 12. *Schistaspis bretonensis* n. sp. Dorsal view of holotype. x 2.

Fig. 13. *Schistaspis bretonensis* n. sp. Dorsal view of second specimen. x 2.

Fig. 14. *Schistaspis bretonensis* n. sp. Drawing of holotype to indicate the fractures and slips within the cephalic shield. The corner a_1 has slipped under the main body of the shield A.

PLATE I



Secondary Processes in Some Pre-Cambrian Orebodies.

By R. C. WALLACE, M.A., PH.D., D.SC., F.G.S., F.R.S.C.

(Read May Meeting, 1922)

The accumulated results of investigations in the Pre-Cambrian areas of Central Canada have demonstrated that glacial erosion in Pleistocene times has been fairly complete, and that, where any considerable secondary changes are found in exposed Pre-Cambrian rocks or orebodies, conclusive evidence must be adduced to support any theory of pre-glacial weathering. It will be recalled that Van Hise suggested that the limited occurrences of haematite orebodies in Canada, in contrast to the extensive deposits in Minnesota and Wisconsin, might be explained by the greater ice erosion in Canadian territory.[1] Secondary changes in surface exposures are in general of small importance in Canadian Pre-Cambrian territory southeast of Hudson's Bay with which the writer is familiar. Where weathering is pronounced, therefore, it is of some interest to investigate the factors which have led to the rapid changes, both in oxidation and reduction, which have taken place since glacial times—if, indeed, the changes are all to be relegated to the post-glacial period.

SULPHIDE BODIES IN NORTHWESTERN MANITOBA

The mineralogy and mode of origin of the sulphide deposits in the Athapapuskow district of Northern Manitoba have been somewhat fully discussed elsewhere,[2] and for the purposes of this paper it is necessary to make only the briefest reference to the primary mineralization. In the Mandy and Flin-Flon orebodies, which have been formed by replacement processes in sheared and faulted zones, pyrite, chalcopyrite, sphalerite, and galena are the important primary minerals, and the order of deposition was, in general, the order given in the above list. In several of the other sulphide occurrences in the same district, pyrrhotite is found associated with pyrite and chalcopyrite, more rarely with sphalerite or galena. The sulphides are

[1]U.S. Geol. Surv. XII, Ann. Rep., Pt. III, p. 411.

[2]Bruce: Amisk Athapapuskow Lake District. Memoir 105, G.S.C. Econ. Geol. 15, 1920, p. 386.

Hanson: Econ. Geol. 15, 1920, p. 574.

Wallace: Mining and Mineral Prospects in Northern Manitoba. Northern Manitoba Commission Bulletin. Bull. Can. Min. Inst., Feb., 1921, p. 106.

either in intimate mixture, with a relatively small amount of country rock in evidence (the "solid" sulphides of the Mandy and Flin-Flon orebodies), or somewhat coarsely crystallized in the greenstone schist and not closely intergrown (the "disseminated" sulphides near the wall rock in the orebodies, and in the sulphide occurrences throughout the district). In general, the exposures are found in the valleys which represent lines of shearing or faulting. An unmineralized "horse" in the orebodies, or a lens of rich chalcopyrite, stands out prominently in sulphide bodies which are otherwise much below the average level of the Pre-Cambrian surface in that area. In this respect the sulphide mineralization in greenstone may be contrasted with gold mineralization in quartz veins in the same mineral area where the veins not infrequently occupy positions of marked relief. Only in one type of sulphide mineralization are the exposures found normally on the higher rock ridges, and with this type of deposit we are not concerned in this study. On the northeast arm of Lake Athapapuskow, veinlets of bornite and chalcopyrite traverse a greenstone which has been to such a degree hardened by epidotization during the process of mineralization that it has proved more resistant than the unmineralized greenstone.

Oxidation and Reduction Processes

Except where they occur in the epidotized basalt, the sulphides of iron and copper have suffered very considerable oxidation and subsequent reduction. The changes are most pronounced in the disseminated ore, and of less importance in the massive ore, particularly when rich in copper. In the pools which rest on the low hollows in the mineralized areas, ochres are precipitated, and a capping of limonite or haematite forms a red gossan on the sulphide bodies, visible from considerable distance. Trenches dug in the valleys underlain by disseminated sulphides pass through (1) limonite, (2) haematite, (3) loose unoxidized sulphide, before reaching solid rock. No sampling is possible unless at the bottom of trenches at least 15 feet deep. With "solid" sulphide ore, oxidation is unimportant. In the case of the lens of rich chalcopyrite ore in the Mandy orebody (20% Cu), the ore was discovered underneath the moss, practically unaltered, forming part of the highest ridge on the property.

Taking the sulphide bodies as a whole, the primary mineralization consists of pyrrhotite, pyrite, chalcopyrite, sphalerite, galena, bornite, and probably chalcocite. Oxidation products are limonite, haematite, melanterite, chalcanthite, azurite, and malachite. Reduction minerals are covellite, native copper and, doubtfully, chalcocite. To this list of metallic minerals there should be added the non-metallic oxidation product gypsum, which occurs in cavities in the oxidized zone, which were presumably occupied previously by pyrite. In the case of the Flin-Flon orebody, which has been more accessible for study by reason of the exposures obtained by mining operations, the most extensive weathering occurs immediately east and north of a high horse of unmineralized fairly massive greenstone at the south end of the property.[1] In this weathered area a rather peculiar type occurs. Immediately east of the horse a highly porous, pumice-like silica rock is exposed. From the underground sections of this rock it would appear to have been a quartz porphyry in which, on mineralization, the feldspar had been replaced by pyrite and secondary silicification had taken place. On oxidization, the pyrite has been removed, leaving a vesicular rock which is mainly silica.

Much of the oxidation material has doubtless been removed from the vicinity of the sulphide bodies by surface agencies. Some of it has, however, penetrated downwards, and has in lower levels been reduced to other minerals. Covellite is rare, but was found in the Mandy orebody. Native copper is not uncommon in fine scales in the rock fissures even at the surface of several sulphide bodies, and was found in a flat dendritic mass of crystals when sinking the shaft near section "D" of the Flin-Flon orebody at a depth of 60 feet. At this depth the shaft, which had been sunk in greenstone, encountered solid sulphides. The native copper lay on the surface of the solid sulphide, the copper bearing solutions having evidently migrated downwards in the water bearing zone between the greenstone and solid sulphides. As this zone has not been sectioned elsewhere except at the 100 and 200 feet levels, the probability remains that considerable masses of native copper may have been deposited in this zone. Chalcocite has not been found in the Flin-Flon orebody, but was seen by the writer in the Sunbeam group, west of Hook Lake, where the mineral occurs mixed with chalcopyrite at the bottom of a pit 12 feet deep. There is no suggestion of secondary enrichment in the mineral association, and the occurrence is considered by the writer to be primary.

In studying in further detail the process of oxidation, one notes that the action is most complete where pyrite—or pyrrhotite—has been crystallized in the original replacement process in association with considerable country rock. Where the replacement process has gone further, and an intimate mixture of sulphides with relatively little country rock has been the result, oxidation is not so pronounced.

[1]See Wallace, Bull. Can. Min. Inst., Feb., 1921, p. 106.

The starting point for the oxidation is undoubtedly pyrite, and that because of the acid liberated on taking up oxygen.

$$Fe\,S_2+H_2O+7O=Fe\,SO_4+H_2SO_4$$

This has already been fully emphasized in the literature of secondary enrichment. The free acid acts on chalcopyrite and cupric sulphate is formed and carried downwards, with further formation of acid:—

$$Cu\,Fe\,S_2+2\,H_2SO_4=Cu\,SO_4+FeSO_4+2\,H_2S$$

$$2\,H_2S+8O=2\,H_2SO_4$$

Whether the greater porosity of the disseminated sulphide rock, thus admitting of freer entry of oxygen, and readier downward movement of the sulphate solutions, is the only important factor in the readier oxidation of the scattered sulphide bodies, has not yet been definitely determined. In some experiments which they carried out with various sulphides, Gottschalk and Buehler[1] found that when the sulphides were in intimate contact, the electromotive force which was established on oxidation of the pyrites (or marcasite) led to the protection of the pyrite (or marcasite) from further oxidation. The writer is of the opinion that differences of porosity cannot sufficiently account for the differences in oxidation, and that the principle which Gottschalk and Buehler established in their experimental mixtures may hold in the intimately mixed sulphides of parts of the Mandy or Flin-Flon orebodies, and that the active source of oxidation processes —pyrite—may thereby be protected from further oxidation.

The most interesting phase of the reduction process is the formation of native copper. As already noted, native copper is found not only in minute scales in the fissures at or near the surface in many properties, but has been found in comparatively large crystal aggregates at a depth of 60 feet in the Flin-Flon orebody. It is known that the chemical action

$$2\,Cu\,SO_4+2\,Fe\,SO_4\rightleftharpoons Cu_2SO_4+Fe_2(SO_4)_3$$

is reversible,[2] and that the action goes almost entirely towards the right at a temperature of 200°C. The hydrolysis of $Fe_2\,(SO_4)_3$ doubtless affects the balance of this action, even at lower temperatures, as ferric sulphate is thus removed from solution by the precipitation of ferric hydrate. It is also known that from cuprous sulphate copper is readily deposited according to the equation

$$Cu_2SO_4=Cu+Cu\,SO_4$$

more particularly, it would appear, in the cooler parts of the system.[3]

[1]Econ. Geol. 7, 1912, p. 15.

[2]See R. C. Wells. Econom. Geol. 5, 1910, p. 205.

[3]Stokes: Journ. Geol. I, 1905-06, p. 647.

The oxidation of ferrous sulphate to ferric sulphate and the subsequent hydrolysis of the latter with formation of limonite has undoubtedly been widespread. If the reversible equation

$$Cu\,SO_4 + Fe\,SO_4 \rightleftharpoons Cu_2SO_4 + Fe_2(SO_4)_3$$

be considered a closed system, it is fairly certain that at no time in the history of the orebody since the original replacement, least of all since glacial times, have the temperatures been sufficiently high to permit of any considerable amount of cuprous sulphate being formed. The explanation here suggested is that cuprous sulphate was formed, but not in a closed system. In any balanced action, at any temperature, all the constituents are represented, even though the constituents on one side of the equation may be present in very small amount. The hydrolysis of $Fe_2(SO_4)_3$, and the precipitation of native copper from Cu_2SO_4, would by the removal of both constituents from the system permit of further formation of Cu_2SO_4 and $Fe_2(SO_4)_3$, as a continuous process even at ordinary temperatures. The associations of native copper in the Flin-Flon orebody would indicate that the process

$$Cu\,SO_4 = Cu + Cu\,SO_4$$

takes place most readily in the presence of pyrite and chalcopyrite.

The Age of the Secondary Processes

In recent years the question of the possible existence of pre-glacial weathered surfaces in Canadian Pre-Cambrian territory has frequently been raised. The discussion of Whitehead and Bateman on the one hand, and of Tyrrell on the other, on this matter, as arising from the oxidation in the Cobalt territory, may be cited in this connection.[1] Cross[2] has noted the existence of a kaolinized syenite in the Mattagami River which may possibly have been weathered in pre-glacial times. Keele[3] has described unconsolidated sands of probably Mesozoic age in the northern fringe of the Pre-Cambrian in Ontario, which were untouched by glaciation. Coleman[4] had found, however, that unoxidized sulphides immediately underlie the glacial drift in the Sudbury field and relegated the oxidation in that field entirely to post-glacial times. The conclusive evidence in any field is, of course, that furnished in the relationship of the oxidized material to the glacial drift, where such exists. In the Flin-Flon district, glacial drift is

[1]Econ. Geol. 15, 1920, pp. 103, 453; 16, 1921, p. 558.

[2]Ont. Bur. Mines, xxix, 1920. Pt. II, p. 17.

[3]Trans. Roy. Soc. Can. xv, 1921, p. 43.

[4]Ont. Bur. Mines, xiv, 1905, pp. 101, 163.

relatively unimportant, and furnishes no clue, so far as ascertained, in the immediate vicinity of the orebody. The direction of flow of the ice-sheet in this district was approximately southwestwards, and the high horse of unmineralized rock immediately west of the most highly oxidized part of the sulphide body could, therefore, have formed no protection against the erosion of the gossan in the valley. How deep the gossan cap may have been in the valley before the ice-sheet advanced there is now no means to determine. Conditions were favourable for deep weathering in late Pre-Cambrian time, in late Palaeozoic and early Mesozoic times, and again in late Tertiary times, representing periods of high elevation in this area with maximum differences between surface and water-table levels. During Ordovician, Silurian, Devonian, and again in Cretaceous times, the sulphide bodies were probably under water, and protected from erosion. Even if the earlier history of the orebody be left out of consideration, conditions during the later periods in Tertiary times were such as to give rise to widespread disintegration of elevated orebodies, and doubtless a deep capping of gossan covered the Flin-Flon and other disseminated sulphides in trench-like valleys. Under such conditions it is at least possible that the ice-sheet would not pick up the oxidized sulphides of the lower levels. It might be expected, however, that if the erosive power of the ice were lessened to that extent some glacial drift would be deposited in the trench over the untouched gossan as the ice passed on.

This drift has not been found in any section of the weathered sulphides. The conclusion has been reached, after comparing the unprotected solid sulphides of the Mandy orebody, which are unweathered, with the disseminated sulphides elsewhere in the district, which are deeply weathered, that the secondary processes are post-glacial in age, and that their relative magnitude is due to the porous nature of the rock in which the disseminated sulphides occur, and to the fact that the pyrite—or pyrrhotite—is less intimately in contact with the other sulphides than is the case in the solid ores.

The Eastern Belt of the Canadian Cordilleras,[1] *An Inquiry into the Age of the Deformation*

BY D. B. DOWLING, D.SC., F.R.S.C.

(Read May Meeting, 1922)

INTRODUCTION

The threefold division of the Canadian Cordilleras into Eastern, Central, and Western Belts, is based mainly on topographical characteristics, though age and structure have left an impress that is in general harmony with the division as made. The Eastern belt was the last to be formed and in the main is the most rugged, hence the collective name "the Rockies". Its structural features are unlike those of the older ranges to the west, being predominantly the product of great crustal compression which produced not only close folds but also great overthrust faults giving rise to a type of structure that has acquired the designation *Rocky Mountain structure.* The eastern part of the Eastern Belt has this Rocky Mountain structure which thus *associates* three unit members into the Rocky Mountain system, viz., the *Rocky Mountains*, *Mackenzie Mountains*, and *Franklin Mountains*, each with a similar structure but probably not a common history. These mountains although rudely aligned are not directly connected except by the older ranges against which they rest.

The *Rocky Mountains* consist of a well aligned and almost parallel series of ranges which have their maximum width at the western border of central Alberta, but become much reduced and practically die out before reaching as far north as the northern boundary of that Province. The *Mackenzie Mountains*, which are much wider and have a curving outline, consist of somewhat irregularly folded masses flanked on the east by approximately parallel ranges of folds and overthrusts which extend far to the east of the general alignment of the Rocky Mountains. The *Franklin Mountains* are a minor range of folds in front of the Mackenzie Mountains. Structurally they are genetically related to the Mackenzie Mountains and may be merely an early expression of the forces which later built the mountain masses to the west.

The formation of the above series of mountains is generally supposed to have taken place during the latest period of Canadian mountain building, when the interior of the continent was raised

[1]Published by permission of the Director, Geological Survey, Ottawa.

from near sea-level to very near its present elevation. But there is presumptive evidence that an area in the north was uplifted earlier than the central part of the continent, that it was above sea during early Carboniferous time and was again elevated before the retreat of the Cretaceous sea took place in the south. It seems possible, therefore, that mountain building took place earlier in the north than in the south. Had all three of these mountain groups formed contemporaneously it is unlikely that the existing diversity of alignment and break in continuity would have resulted.

The Geosyncline

The region of the Great Plains and the eastern border of the Cordillera previous to the formation of the mountains of the Eastern Belt as disclosed in the sections of the now deformed strata was an area in which deposition, mainly marine, persisted from early geological time. In places, especially in the southern section, there is evidence of a pre-Cambrian deposition comparable in amount to that of the eastern margin of the continent as found in the Gold-bearing series of Nova Scotia. Some of this material may have come from the east, but the increasing thickness of the deposits westward points to derivation from a long continental mass, the remains of which now form the Central mountain belt. These early sediments were followed by Palæozoic limestones and Mesozoic sediments which also display characters that point to a western source of origin but were spread out in more even sheets than the earlier strata.

The Older, Western Division of the Rocky Mountains

The early sediments which appear in the geosynclinal region in such enormous masses were probably restricted in their area of deposition and may have produced a local overloading which probably would contribute to the downwarping of the geosyncline and the presumably long continued upwarping of the land mass to the west from which the sediments were derived. Other causes of the upwarp of the western land area were of a different order. Thus the batholithic intrusions credited to Jurassic time and represented by the granitic masses in southern British Columbia and along the coast would probably accompany differential movements productive of normal faulting in the land area. This period may reasonably be assumed to be the one in which commenced the advance of the earliest Cretaceous sea. A second period of granitic intrusion[1] in southern

[1]Camsell, Fraser Valley, Trans. R.S.C., Vol. XIV, 1920, Sec. IV, p. 45.

British Columbia, somewhat younger than the early Cretaceous sediments of the area but pre-Tertiary in age, may have been contemporaneous with earth movement which at the close of the Kootenay period changed the outline of the Cretaceous seas east of the old land barrier and may also have been contemporaneous with other movements later referred to.

In mid-Cretaceous time the Cretaceous sea was expelled for a short period from the geosynclinal region but entered again from the south and attained greater width than before, but apparently did not connect with an encroaching sea which extended a short distance southward from the Arctic coast. During this period of expansion of the seas and accompanying subsidence of the basins, any stresses due to an adjustment of load would probably produce tension in the crust along the margin of the depressions and compression in the basin areas. That is, normal faulting would probably occur, especially along the western side of the greatest depressions.

If there is a genetic relation between deep depressions and nearby great elevations as is argued for in the case of the Indo-Ganges trough and the Himalayas, then the Selkirk massif may be considered as directly related to the former great geosyncline which persisted to the east through all of Cretaceous time. The existence of this basin, now modified by the general uplift and upturn of its western edge accomplished in Tertiary time, has been fully proved by information obtained from exposed sections and drilling records. Its present form is illustrated in Figure No. 1 based on a figure reproduced in Memoir 116 of the Geological Survey. This figure shows that the deep part of the basin is now close to or even within the present mountains. That the present deepest parts of the basins approximately correspond with the original deepest parts may be deduced from the known thicknesses of the different formations and the way in which these thicknesses vary. The contours of the basin as it now exists, suggest that a governing line existed which helped to maintain the parallelism of the outer mountains. This governing line, it is thought, owed its origin to the existence, as already suggested, of tension with accompanying normal faulting in the crust at the western edge of the subsiding basin. The great amount of this subsidence near the western land, it is thought, would result in the rising during Cretaceous time along the western margin of the subsiding area of a fault block fronting a former fractured land mass and presenting to the sea a wall comparable to that of the coast of Labrador. The presence of this block east of the older land area is disclosed by the areal distribution of the geological formations, which shows that a division may be made in the Rocky Mountains between an eastern area in which later Palæozoic and younger sediments are predominant and a western one in which Cambrian and older strata are mostly in evidence. The dividing line, where it crosses the Bow valley and incidentally is opposite the deepest part of the present Alberta syncline, is marked by a steeply dipping fault plane with a maximum downthrow to the east estimated at thirty thousand feet. Westward to the Beaverfoot valley this fault block is but slightly deformed and dips gently westward. A thickness of five miles of material has been removed from its eastern edge which could not have been elevated and denuded within the same space of time that may be allowed for

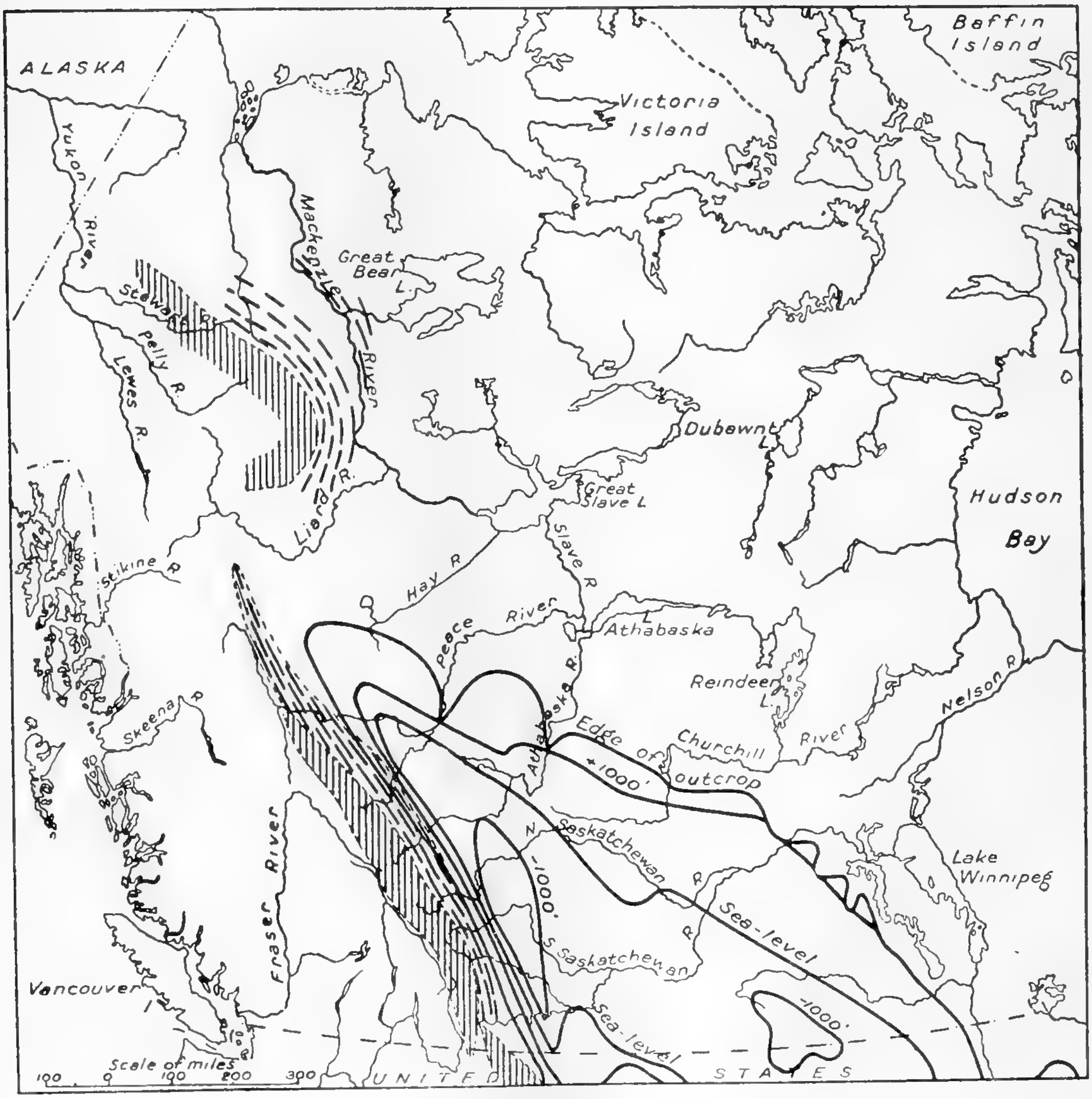


Figure 1

The divisions of the Rocky mountains (areas marked by vertical lines represent the earlier formed ranges) and outline of area occupied by Upper Cretaceous sediments (contour lines indicate shape of the bottom of the basin).

the slight denudation in evidence in the outer ranges. Therefore, for this southern area of the "Rockies" the assumption is made that previous to the formation of the outer Rocky Mountains the land mass as it rose widened mainly by the successive appearance of great blocks separated by normal faults, and that at about the beginning of Cretaceous time one long block appeared which widened the land mass along the western side of the sinking basin and by its gradual rise and straight bounding fracture, preserved the general straight and steep western shore of the basin.

This block was possibly the last to appear and is now incised, trenched, and slightly folded and on account of its position east of the Rocky Mountain Trench is included in the Rocky Mountains.[1] It extends northward from somewhere near Fernie, *i.e.*, between Fernie and Elko, and attains its greatest width west of Castle Mountain. It is not definitely shown in the sections of the mountains at Peace river and on the Liard, but at Jasper Pass it maintains its width and is compressed into a broad syncline from the central part of which is carved the mass of Mount Robson. It is not clear that its western edge is separated from the old land mass by a fault, but along its eastern edge the great downthrow of a normal fault is in evidence. It thus appears from these several sections that a distinction can be made in the Rocky Mountains between an eastern terrane consisting of measures in part as young as Cretaceous and showing overthrusting and folding, and a western terrane eroded from a large elevated section of the stratified crust whose deformation outside the intense sculpturing consists of gentle folding parallel to the general mountain structure.[2] This gentle folding resulted during a period of compression followed by the intrusion of an alkaline complex of laccolitic nature and a period of normal faulting. The age of this deformation has been stated to be as that of the Laramide revolution, *i.e.*, late Eocene.

It has been argued that previous to this deformation, the drainage was eastward across the block and that the formation of a drainage system normal to this direction was due to normal faulting in a period of tension in Tertiary time[3]. It is not very evident that there has been a general period of tension since the overthrusting at the close of the Eocene and there seems no reason to assume that all the great valleys tributary to the Rocky Mountain trench were excavated since that time. It seems just as reasonable to suppose an earlier history for

[1]See Fig. 1.

[2]J. A. Allan, Field Map area, Memoir 55, p. 207.

[3]Schofield, Rocky Mountain trench, Trans. R.S.C., Vol. XIV, Sec. 4, p. 81.

the general scheme of normal faults so evident in the Selkirk system and a longer period for denudation and trenching. The period of compression at the close of the Eocene might well be credited with minor folding in the fault blocks and also some faulting as noted below. To this period is assigned the elevation of the plains and the formation of a great anticlinorium on the site of the Rocky Mountains. The western edge of this arch rests against the older mountains and in places the outer normal fault block within the Rocky Mountains appears to have been further tilted westward as a part of the arch, thus intensifying the grade of the drainage from the east into the trench. Where this has occurred, as along the Kicking Horse valley, the hinge of the tilting may well have been near the Rocky Mountain trench and have developed there the structure which now appears as a graben but which in reality may be a slight elevation of the eastern block from the effect of the compression. Along the outer normal fault forming the eastern edge of the fault block of the western part of the Rocky Mountains, the arching has in places modified the fault line and the compression appears to have produced some overthrusting to the east which is, probably, most evident in the Athabaska section where the compression has thrown the fault block into a syncline, but is also in evidence near Mount Assiniboine, though in less pronounced form.

The age of the major normal fault forming the boundary between the two divisions of the mountains is somewhat uncertain. This displacement if, as already suggested, it resulted in the production of a coastal or land wall, should be marked by coarse material deposited along its front. The deposits which might have shown the exact foot of the supposed escarpment p.obably would be removed in the process of mountain building, but an examination of the nearest Cretaceous deposits of the suspected period of great displacement is of interest.

The Cretaceous deposits so much in evidence on the plains indicate periods either of shallowing of the sea or of revived denudation of land areas, followed by subsidence. The maximum subsidence and the greatest areal extent were reached in the Colorado period. The best available sections of the deposits near the western margin are those remnants found within the mountains and of these the most important are in the Elk River valley.

Very coarse conglomerates there appear in places to cover the marine shales of the Jurassic and are found in various parts of the land deposits of the Lower Cretaceous (Kootenay formation). They occur in greater amount above this formation in the Elk conglomerates and Flathead beds now forming the summits of the mountains in the Crowsnest coal field. The land deposits of the Kootenay formation also include coal measures and are largely composed of coarse sediments. Their thickness is estimated at about 6,000 feet while the conglomerate series above them is placed at a maximum of 6,500 feet.[1] The amount of material piled on the marine floor of Jurassic sediments in the west was thus from 12,000 to 13,000 feet,[2] but in the Foothill section it is only 1,500 feet,[3] showing that the mass had a wedge-like section. It is assumed, therefore, during the deposition of these beds, a subsidence took place which approximated 13,000 feet or more. The character of the debris is also an indication of the nearness of the source of supply and we can conceive of either a land mass produced by an upwarp and, therefore, giving a low gradient for the transport of material produced by its denudation or, a bodily elevated fault block fronting a subsided surface. The second conception seems the more probable, especially in view of the break already mentioned as forming the dividing line between the two parts of the Rocky Mountains. Its position in the district is a few miles west of the deposits discussed and, therefore, it is claimed as the mechanical instrument responsible for the building of the wedge of coarse debris. It seems reasonable to assume movements at this fault line as early as the beginning of the Cretaceous with probably a major period of movement at the close of the Kootenay period. The amount of material removed from the uplifted area is so far in excess of that removed from the area to the east that an early subjection to erosion is a necessary postulate and it is put forward here that the western Rockies appeared first in Mid-Cretaceous time, although earlier uplifts of the same mass are no doubt indicated in the conglomerates of the Kootenay which are so persistent and extend as far north as the Smoky River coal basin.

The former extent of the Elk conglomerates can only be conjectured as in the process of mountain building they have been removed, north of the locality cited. They probably occupied the foot of the wall formed by the normal fault which divides the mountain mass and would be limited by its extent and probably by the amount of displacement. It may be that a large part of the displacement, especially to the north, occurred during the deposition of the Kootenay measures and that to the northward the movement recorded by the Elk conglomerates was limited in amount.

[1]Guide Book No. 9, p. 24, Geol. Surv., Can.
[2]Summ. Rep. 1900, p. 90A, Geol. Surv., Can.
[3]Memoir 31, p. 34, Geol. Surv., Can.

The Younger, Eastern Division of the Rocky Mountains

The subsequent history of the basin to the east of the earlier formed mountains as disclosed in the character of the later sediments is: first, a narrowing of the sea, probably largely confined to the northern half of the Canadian area; then a widespread subsidence of the southern half; and, lastly, a final retreat of the sea from the north accomplished in two stages as registered in the shore deposits. In general, after the subsidence, there was an extended period of tranquillity closed by an uplift, along the western margin, consisting of short periods of uprise and settlement during which the Belly River series was deposited, and then followed a partial advance of the sea before its final retreat during which the Edmonton formation was laid down. The movements during this period probably indicate alternating compression and tension in the crust and no doubt some deformation was accomplished in the land mass to the west. In the north the later Cretaceous sediments were probably land deposit, but as they have largely been removed we can only surmise that the compressive strains which, in the north, caused deformation before the deposition of the Tertiary measures, were contemporaneous with the general uplift marking the disappearance of the Cretaceous sea.

The early Tertiary sediments, generally freshwater deposits, indicate a period of continued uplift made apparent by the mass of sands and clays deposited in the western part of the area and denoting an increase in the grade at the western margin of the region, while the central part to the east was undisturbed and became a brackish lake. Certain refractory clays distributed during an early stage of this lake basin are said to be derived from the Archæan surface to the east. The material is also given an eastern source because of its purity in the east and its admixture with less refractory clay in the west. The present uptilt in the west is thus a later movement and one more nearly connected with the general deformation of the outer ranges.

The coarse sediments, mainly heavy conglomerates, which cap the Cypress Hills and are unconformably above the Eocene beds, are generally attributed to the denudation of the then newly risen mountains. The age of the beds as determined by vertebrate remains is Oligocene. The last mountain building and the deformation of the Tertiary and Cretaceous measures, especially near the mountains, is thus placed at the close of the Eocene and is probably contemporaneous with the period of vulcanism in the interior of British

Columbia. The deformation of this time includes the elevation and upthrust of the Rocky Mountains. A northern limit for the region affected seems indicated by the available information because the folding and displacement in the Rockies show a decided decrease northward, and at the Liard river consist only of an anticlinal fold with Mesozoic rocks on either limb and an arch in the foothills showing Triassic rocks on its crown. Beyond this to the north, uplift and deformation appear to have been of an earlier date. At least a partial uplift occurred before the Cretaceous sea was expelled from the southern basin.

The Northern Mountains

North of the sixtieth degree of latitude the mountains do not lie along the western limb of the great geosyncline as in Alberta, but proceeding northward cross it diagonally from west to east and reach to near the eastern edge. Compared with the southern region the thickness of the sediments is reduced, partly by a lessening in the amount of sedimentation during the period between Devonian and early Cretaceous and partly by early denudation. Deposition of Cretaceous sediments was also limited to an early period. A great part of the mountain structure is due to compressive strain and must have formed during intervals characterized by the development of such types of strain.

The pre-Cretaceous land to the west was of low relief judging from the occurrence of marine Jurasso-Cretaceous measures over such wide areas in British Columbia and Yukon. The earliest intrusions which might have accompanied disturbances affecting the topography of the time, were the granites of the Coast range, pebbles of which are found in the Lower Cretaceous measures. Intrusions that cut and deform these measures were more widespread and are believed to have occurred previous to the deposition of the Kenai[1] series, the supposed equivalent of the early Eocene.

In the Mackenzie valley the evidence of the age of the period of compression and mountain building is more definite and indicates it as being the close of the Cretaceous. It seems reasonable to suppose that the mountain mass extending westward from this valley was formed in the period represented elsewhere by the latest Cretaceous deposits. The principal evidence of this late Cretaceous date for the deformation is the folded Cretaceous beds, probably not including beds younger than Colorado, and the undisturbed condition of the Tertiary sediments abutting against the fault plane

[1] D. D. Cairnes, Memoir 50, Geol. Surv., Can., p. 115.

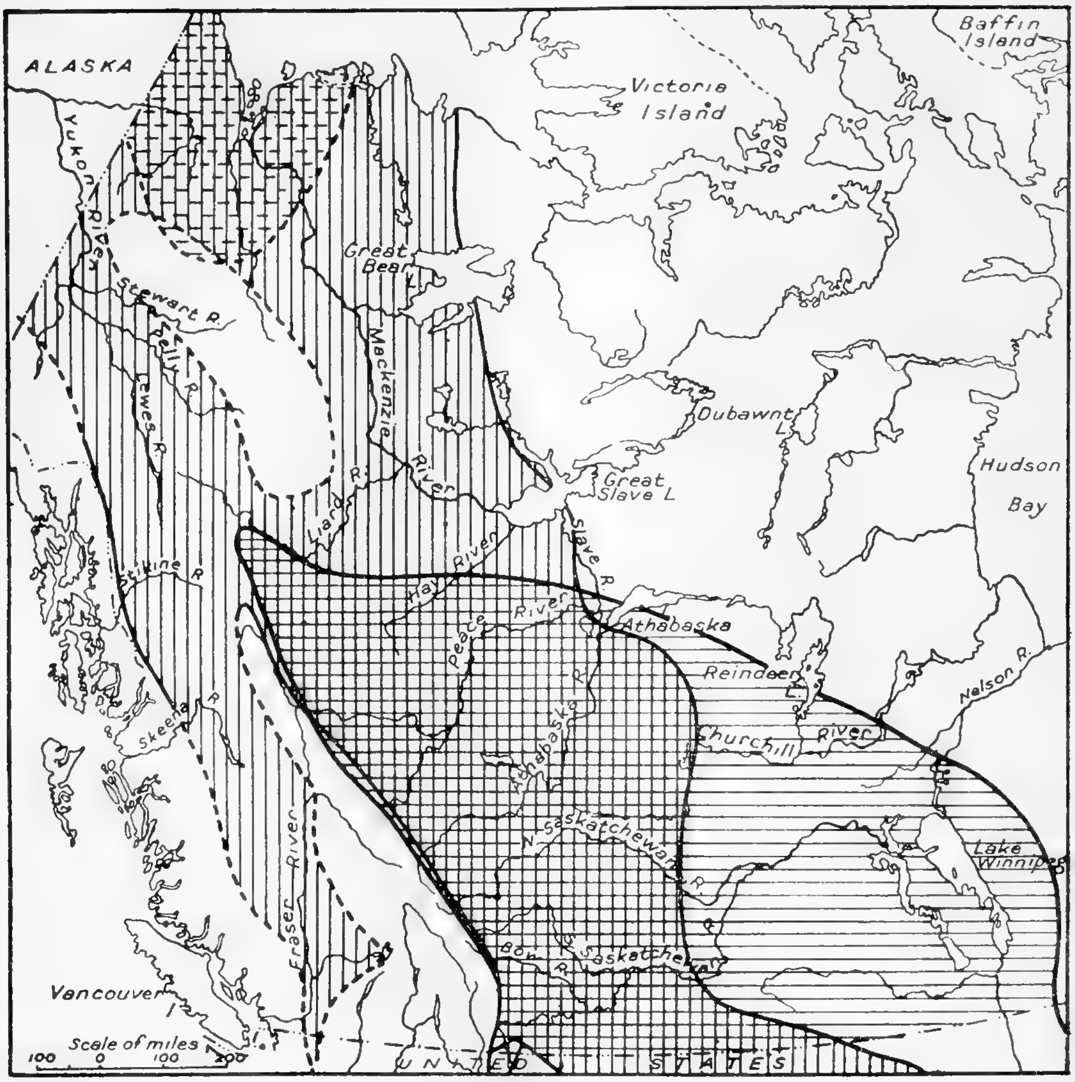


Figure 2

Area involved in the Jurassic-Lower Cretaceous subsidence (shown by vertical ruling) and area involved in the Upper Cretaceous subsidence (shown by horizontal ruling).

which cuts across and truncates the anticlinal ridges of Devonian and earlier sediments. The Tertiary occupies a depression east of this fault or shear plane. The determination of the age of these Tertiary beds depends mainly on plant remains. The correlation made by Sir William Dawson with the Lignite Tertiary of the Plains (the Fort Union of the Cypress Hills and the Porcupine Hill beds) was based on a large range of specimens collected by R. G. McConnell in 1888.[1] If the age should prove to be Late Eocene the northern and southern mountain building periods may be brought closer in time, but cannot be synchronized as the structure does not coalesce.

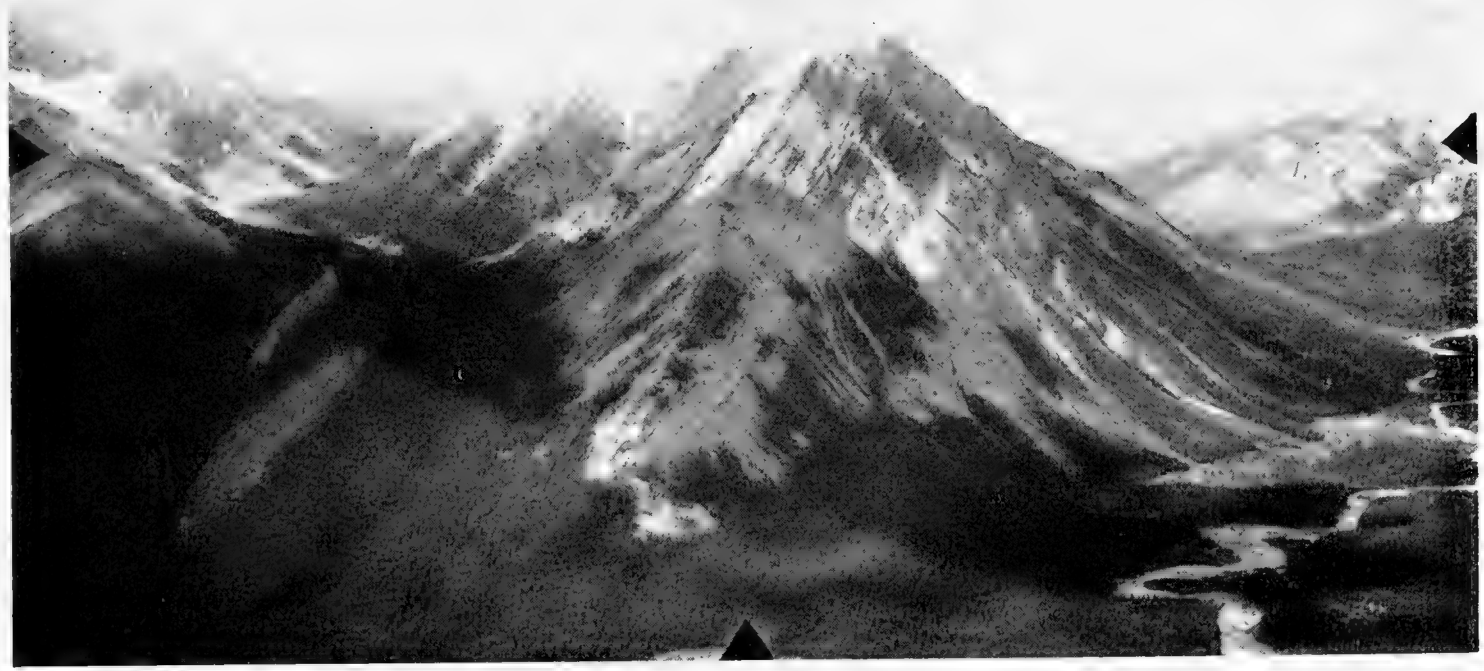
[1]Ann. Rep., Vol. IV, 1888-89, p. 980.

The Mackenzie mountains extend across a region over which Cretaceous and Carboniferous sedimentation was limited or since destroyed and end in a series of plunging anticlines against a terrace of unconsolidated Cretaceous rocks. To the west across a spur or narrow basin of Cretaceous rocks appears a ridge or fold of Palæozoic limestones which is the last or northern end of the Rocky Mountain series of folds and overthrusts. If the vigorous folding of the Mackenzie Mountains was synchronous with that of the Rockies there would be evidence of reinforcement, but as there seems to be no direct continuity of folding it must be surmised that the eastern mountains were formed earlier than this part of the Rockies at least, and that the gap between the two was not closed on account of the dying away of the stress which built the Mackenzie Mountains. Similarly the strains of the later period within the sphere of maximum stress produced deformations (the outer Rockies) that extended to some distance into the Cretaceous basin, but were restricted in the zone of deformation by the heavy load of incompetent beds of the Cretaceous basin. Northward, where this load decreased, the narrowing of the zone as well as the simplifying of the folds denotes a lessening of the strains.

As the great ribbing up of the crust denotes a movement, as well as compressive stresses, the building up of mountain ridges would tend to form dams to stay the advance, so that it would seem reasonable to outline the history of this region by assuming that the early ridges appeared to the east of the area under strain. Under that assumption the outer ranges which are on the right bank of the Mackenzie were first formed. These consist of an irregular chain running about directly north and called the Franklin Mountains. These are nearly joined by an east-west series that have a range of over a hundred miles and have really no general name, but may be generally designated as the Norman ranges. The structure as noted already shows pressure and movement of the crust which for the inception of the period appears to have been northeastward. The line represented by the Franklin ranges is the edge of this movement as the ridges are close folds arranged *en échelon*, while the ridges with east-west alignment indicate folding at right angles to the movement. As these latter terminate eastward in a faulted upthrust and westward in plunging anticlines it is assumed that the formation of the eastern ridges so loaded the crust that outside of the first east-west fold, whose course is not yet fully mapped, simple buckling of the surface occurred until a sheared fault line was developed west of and parallel to the Franklin range. The release of the surface by this shear zone allowed for further northward movement and anticlinal ridges were completed but ended eastward at the line of break.

The downthrow side of this break at Norman forms a fairly large basin and it was in this that the horizontal Tertiary beds were deposited. As the age of these beds at present writing is maintained to be Eocene and of the same age as the Paskapoo and Porcupine Hill beds of Alberta and as they were really correlated with the beds of Cypress Hills and Wood Mountain of Saskatchewan, the assumption is made that the period of folding was near the close of the Cretaceous and before the formation of the outer ranges of the Rocky Mountains.

PLATE I



Overthrust type of structure, head of McLeod river, Alberta.

Photograph by Geological Survey, 1921.

The Blithfield Meteorite

By R. A. A. JOHNSTON, F.R.S.C., and M. F. CONNOR, B.A.Sc.[1]

(Read at May Meeting, 1921)

This meteorite was found by Mr. Joseph Legree on lot 20, concession II of the township of Blithfield, Renfrew County, Ontario—approximately latitude 45° 15′ N.; longitude 76° 47′ W.—on August 13th, 1910.

Mr. Legree's attention was drawn to it by reason of one or two metallic patches showing on its surface and thinking it might be a piece of silver ore he broke it into fragments between hammer and anvil. Some of the broken material was submitted to an assayer for silver determination but with unsatisfactory results. A fragment was later submitted to the senior author of this paper who, recognizing the nature of the specimen, enlisted the good offices of Mr. Legree in recovering as much as possible of the remaining fragments which had fallen into the hands of several people; only two or three pieces were eventually found to be missing—probably representing the material used for assay purposes. The mass was reconstructed as nearly as might be done from the fragments by Messrs. A. E. Foote Company, Philadelphia, and an excellent model made from it.

The fragments, as eventually brought together, weighed 1.83 kilogramme, the original mass probably weighed about 1.9 kilogramme as not much more than 70 grammes could have been included in the missing portions.

In form this meteorite was an irregular block averaging $8 \times 10 \times 13.5$ centimetres in its measurements.

As indicated by the fragments the crust must have been in a perfect state of preservation when the meteorite was found. It was smooth and glossy throughout and possessed of a dark brown colour of varying intensity.

Over about a third of the specimen, including portions of two sides and one end, the surface was undulating and the corner and edges were well rounded; the other end was flattish and bounded by sharp edges; over the remaining portion of the specimen the surfaces were irregular and marked by relatively deep depressions, some cup or saucer shaped, others in the form of angular grooves, and all rimmed with moderately sharp edges. The crust covering the flattish end and the more irregular parts of the specimen was quite uniform in thickness and colour, but markedly thinner and of a paler tint than

[1]Communicated by permission of the Deputy Minister of Mines.

were the portions of the two sides and end previously described; they undoubtedly represented too some of the later fracturings incident to the strains to which the meteorite was subjected in its traverse of the earth's atmosphere.

Internally the meteorite presents a grayish brown micro-granular ground mass traversed by small veinlets of nickel-iron alloy. These veinlets are often interrupted and seldom exceed a millimetre in width. In an exceptional case, however, an expansion of one of them attained a width varying from 3 to 6 millimetres over a length of 25 millimetres. When this expansion was rubbed down to a smooth polish it showed a number of fractures partially filled with siliceous matter which had plainly undergone a certain measure of alteration from weathering agencies. Treatment of the polished surface with dilute nitric acid failed to develop any well defined figure; but under a magnification of 40 to 50 diameters a small area measuring about 4 or 5 square millimetres was seen to possess a finely laminated structure, while the edges of the laminæ presented a very uniform fluted appearance. Other portions of this polished surface examined under like conditions showed a minutely granular groundmass traversed by numbers of fine zig-zag lines meeting or intersecting each other at all angles. They are probably cooling fractures and some of them appear to have been filled or partially filled from still fluid residuum.

In thin section under the microscope the groundmass of the meteorite shows a more or less interrupted network of metallic nickel-iron alloy enclosing irregular patches of enstatite. Some of the enstatite appears colourless in the section, but much of it shows a brownish tinge particularly along the edges in contact with the nickel-iron. This tinge, however, is plainly not a property of the enstatite itself, but is imparted to it through the presence of some as yet unidentified sulphur compounds, for when a fragment of the meteorite is treated with dilute hydrochloric acid disengagement of gases, smelling of sulphuretted hydrogen, is set up and in the end there remains a residue consisting of colourless enstatite with here and there a minute flake of daubréelite, and less often a little graphite.

Cleavage cracks in the enstatite are seen quite frequently to have been invaded by still fluid metal and are now occupied by thin films of nickel-iron alloy.

Optical Properties

For the following data the writers are indebted to Mr. Eugene Poitevin of the Division of Mineralogy of the Geological Survey who has investigated the optical properties of the enstatite of this meteorite according to the methods devised by E. von Federoff, with the exception of the refractive indices which were determined on crushed fragments in oils.

The thin sections taken for observation were selected with the greatest care and the figures here recorded taken individually are the average of not less than ten measurements upon plates showing clearly the emergence of the optic normals.

The mineral is optically positive.

$$X \parallel a,\ Y \parallel b,\ Z \parallel c.$$

$2V_{Na}$ generally 58° but occasionally showing variations of as much as +4°

$$\alpha = 1.657 \pm 0.005$$
$$\beta = 1.660 \pm 0.005$$
$$\gamma = 1.667 \pm 0.005$$

Birefringence $(\beta - \alpha)$ measured $= 0.003$

Cleavages m (110), a(100), $m \wedge m = 88° \ 30'$

Parting η(410).

Chemical Analysis and Examination of the Blithfield Meteorite

By M. F. Connor

The sample taken for analysis was a 20-gramme fragment broken from the interior of the meteorite and apart from a slight brownish tinge which is common to the mass throughout it showed nothing which might be taken as evidence of deterioration.

The fragment was first crushed on a heavy steel plate by gentle tapping with a heavy steel pestle protected by a polished iron cylinder to avoid loss by scattering. The coarse powder thus obtained was subjected to the influence of an electromagnet, and the magnetic portion subjected to further crushing and treatment with a magnetic comb, similar to that devised by E. G. Prior of the British Museum, in order to free as far as possible the nickel iron constituents from non-magnetic materials. This treatment was repeated with the greatest care until inspection with the microscope revealed no foreign matter adhering to the metal. This latter was found to weigh 2.6 grammes and was in the form of minute particles and grains of from 1 to 2 millimetres in diameter.

It yielded on analysis—

Iron	91.62
Nickel	6.69
Cobalt	0.45
Copper	0.08
Manganese	0.01

Silicon	1.04
Sulphur	0.07
Phosphorus	0.16
	100.12

The non-magnetic portion of the sample (being that composed of the sulphides and silicates) presented a main problem in the determination of what sulphides were actually present, in order that the separate analytical results obtained might be used in interpreting the mineralogical composition.

Preliminary chemical examination gave the following indications as to the nature of the sulphides:

1st.—A slight odour of sulphuretted hydrogen was noticeable during the fine grinding of a portion of the sample in an agate mortar, and unmistakable sulphide stains were indicated when the powder was dried on a bright copper plate. A one-gramme portion was then boiled in water in a flask provided with suitable means for examining the evolved gases. These latter gave convincing proof of the presence of sulphuretted hydrogen, and after three hours' boiling the liquid from the flask gave after filtration a very distinct reaction for calcium with ammonium oxalate. Upon these grounds it is suspected that oldhamite is present in the meteorite.

2nd.—When another portion of the ground sample was treated with hydrochloric acid much sulphuretted hydrogen was evolved and notable amounts of iron passed into solution. The usual inference was accepted that troilite is an abundant constituent, and its amount is given by computing the Fe S, based on the total sulphur remaining after deducting any amounts required for all other sulphides proved to be present in determinable amounts.

3rd.—Chromium was found by chemical means to be present entirely combined with iron as sulphide leaving no reasonable doubt that the presence of daubréelite in small amount as one of the constituents has been established. The determination of its amount made it possible to allot the percentages of sulphur and iron as required in the calculations for daubréelite and troilite, and to state the percentage of iron oxide in the non-magnetic portion.

In regard to the method used to establish the nature of the chromium-sulphur compound after considerable search that of J. L. Smith was found and successfully applied in a modified form (see separation of daubréelite in the Butcher meteoric irons of Coahuila, American J. Science, p. 270, Vol. XVI, 1878).

A weighed portion was digested with hydrochloric acid in a flask through which a current of hydrogen was transmitted to prevent oxidation during the process. After several hours the liquid in the flask was filtered. The filtrate besides containing iron due to the decomposition of troilite was assumed to contain any SO_3 existing as such in the sample.

The residue washed with alcohol was extracted with carbon-tetrachloride to extract any separated sulphur and then treated for recovery of any daubréelite according to J. L. Smith's directions with nitric acid in which it is entirely soluble without separation of sulphur, as also noted by that author.

The residue remaining after the filtration of the nitric acid solution of the daubréelite was made up of undecomposed silicate and a little graphite.

The analysis of the nitric acid solution showed it to contain chromium, iron, and sulphur only, and these in almost the exact ratios required by the formula for daubréelite.—Fe S. Cr_2 S_3.

Analysis of daubréelite

Daubréelite of Meteorite		*Daubréelite (theoretical)*
Iron	18.1	x 19.1
Chromium	37.6	x 36.1
Sulphur	44.3	x 44.8
	100.00	100.00

The above figures give respectively the following molecular ratios:—

Iron	0.94	Iron	x 1.0
Chromium	2.1	Chromium	x 2.0
Sulphur	4.0	Sulphur	x 4.0

In regard to the silicates it was found that this portion was almost entirely insoluble in acids and had the composition of enstatite. The treatments to determine soluble silicates were made with dilute and concentrated acids with the following results:—Boiling dilute nitric acid extracted 0.1 per cent CaO and 0.2 per cent MgO, whereas strong nitro-hydrochloric acid under like conditions of boiling but with extended evaporation yielded the following as the result of disintegration:—

SiO_2	1.6 per cent
MgO	1.4
CaO	0.33
Al_2O_3	0.4
Na_2O, K_2O	0.08

The separated and purified silicate (enstatite) was found as the result of two closely concordant analyses to have the following composition:—

Analysis of the separated and purified insoluble silicate (enstatite) being the average of two closely agreeing analyses

SiO_2	59.38
TiO_2	trace
Al_2O_3	1.97
Fe_2O_3	0.24
MnO	0.09
MgO	35.92
CaO	0.97
K_2O	0.14
Na_2O	1.19
	99.90

The figures of the general analysis of the non-magnetic portion of the meteorite are as follow:—

	1		2 (same as 1 with calculations to troilite and daubréelite)
SiO_2	48.51		48.51
TiO_2	0.08		0.08
Al_2O_3	2.39		2.39
Fe_2O_3	2.83 (free)		2.83 (free)
Fe_2O_3	11.73 (combined)		
Cr_2O_3	0.45 (combined)		
MnO	0.17		0.17
NiO	0.30		0.30
CoO	0.04		0.04
MgO	28.32		28.32
CaO	1.00		1.00
CuO	0.09		0.09
K_2O	0.10		0.10
Na_2O	1.06		1.06
H_2O-	0.22		0.22
H_2O+	1.27		1.27
P_2O_5	0.05		0.05
SO_3	0.14		0.14
S	4.95	Troilite	12.70

Graphite	0.19	Daubréelite	0.74
		Graphite	0.19
	103.89		
Less Oxygén	3.69		100.20
	100.20		

The Bulk analysis represents as faithfully as possible the general composition of the whole meteorite. This is in conformity with the usual procedure; while it is recognized that the sample taken for analysis may not be a strictly average sample of the whole meteorite, it may be useful for the purposes of general comparison:—

Bulk Analysis

1		2 (Analytical statement of 1)	
The meteorite as a whole is composed of:—		SiO_2	42.220
		TiO_2	0.069
Silicates	75.16	Al_2O_3	2.079
Troilite	11.04	Fe_2O_3	2.462
Daubréelite	0.64	MnO	0.147
Graphite	0.16	NiO	0.261
Schreibersite	0.20	CoO	0.034
Metal	12.80	MgO	24.638
		CaO	0.870
	100.00	CuO	0.070
		K_2O	0.087
		Na_2O	0.922
		H_2O-	0.191
		H_2O+	1.105
		P_2O_5	0.043
		Graphite	0.165
		SO_3	0.121
		S	4.396
		Phosphorus	0.044
		Chromium	0.243
		Nickel	0.902
		Cobalt	0.057
		Copper	0.009
		Silicon	0.133
		Iron	18.989
			100.257

Explanation of Plates

Plate I.

Two views showing the form of the Blithfield meteorite and the variable character of the crust. $\frac{3}{4}$ natural size.

Plate II.

Blithfield meteorite. Thin section x 58 showing the relation of the nickel iron (black) to the enstatite (white).

Note cleavage cracks in the enstatite filled with nickel-iron.

PLATE I

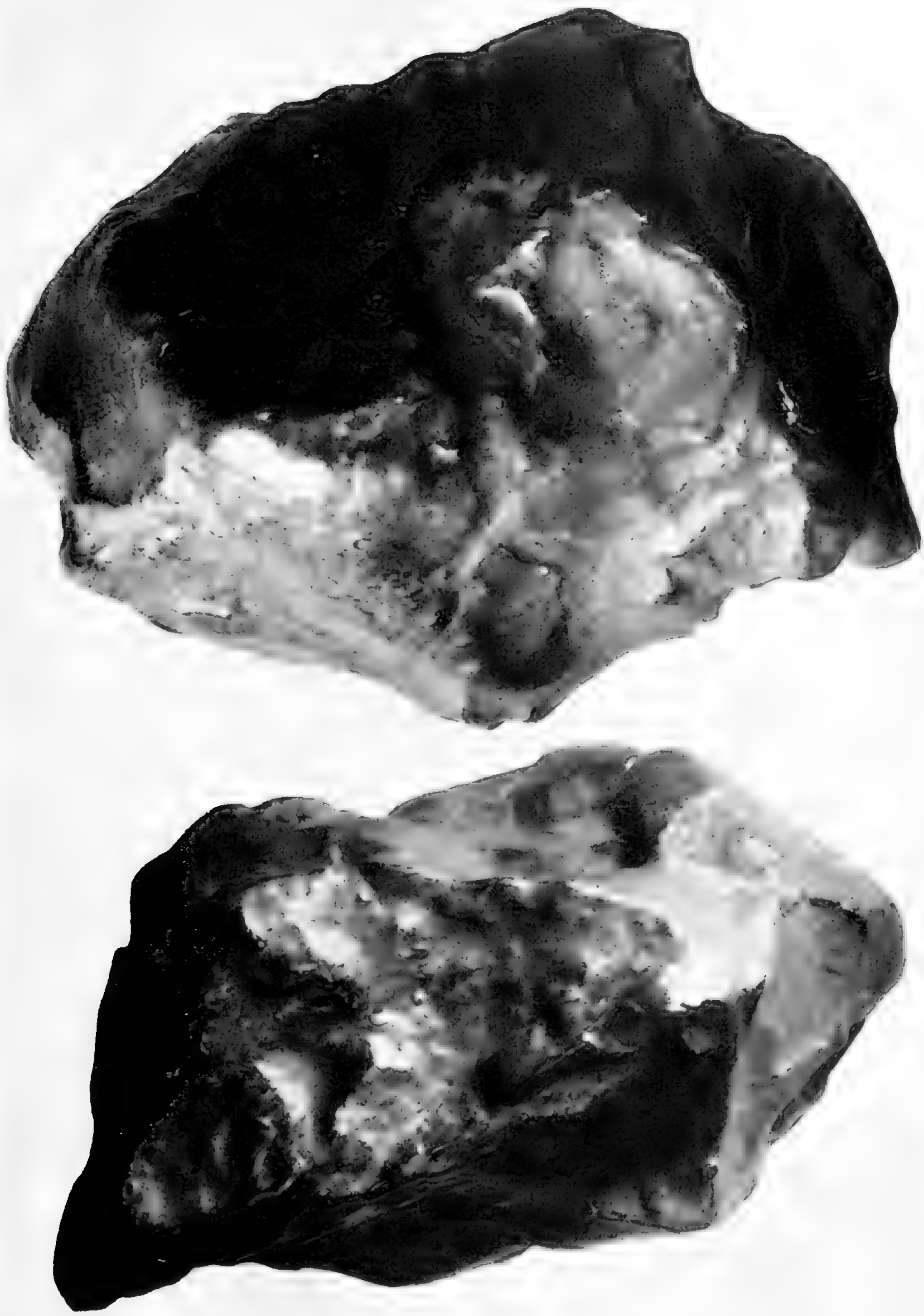
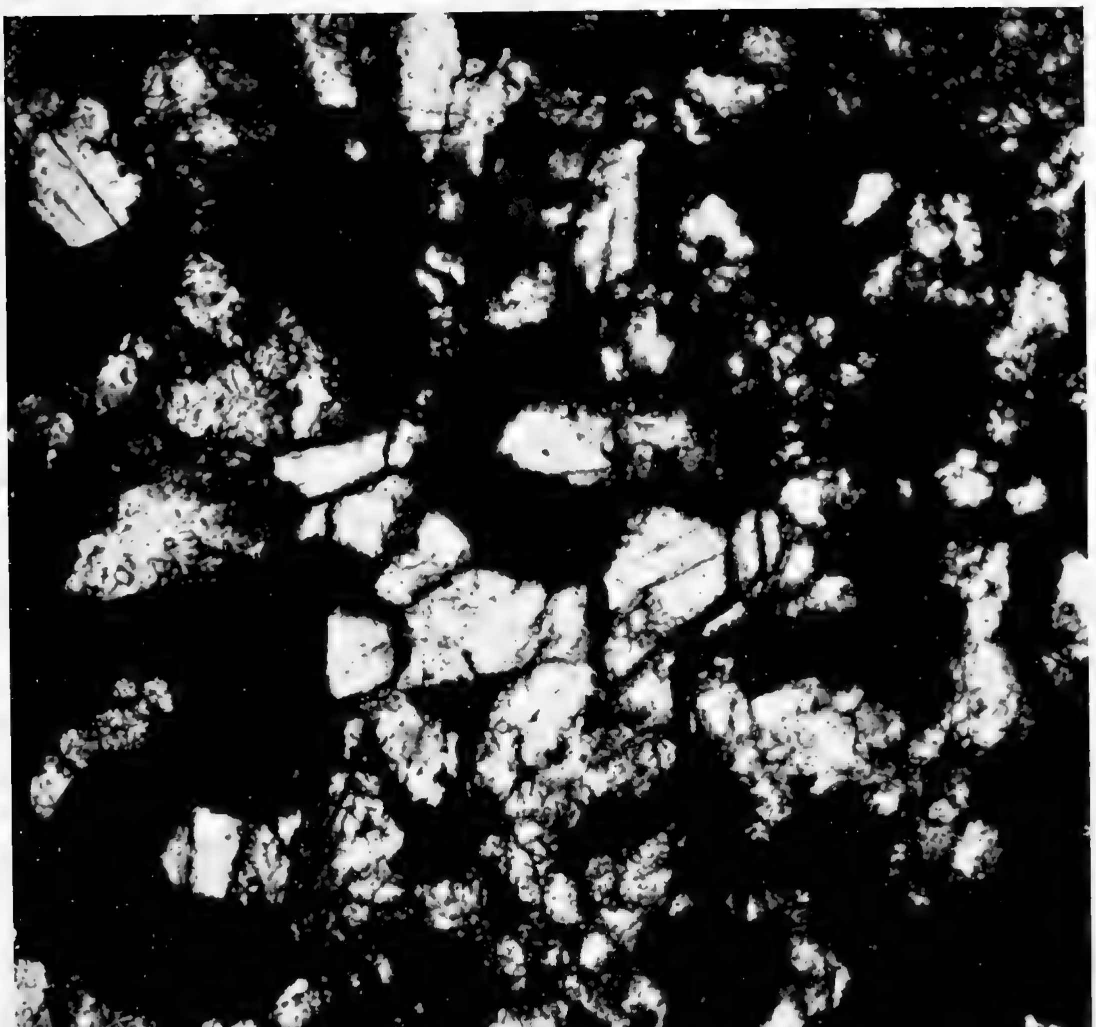


PLATE II



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SECTION V

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I. *The Occurrence and Functions of Tannin in the Living Cell*

BY FRANCIS E. LLOYD, M.A., F.R.S.C.

(Presidential address, Section V, May Meeting, 1922)

In 1913, J. Dekker, of the Koloniaal Museum, Haarlem, Holland, published a Memoir on the Tannins (1913), which is a compilation and critical survey of the whole field, viewed from both botanical and chemical points of view. This work is a monument to the industry of its author, and if omissions are to be found yet it is as nearly complete as may humanly be expected—sufficiently so at any rate to afford a most satisfying and detailed resumé of our knowledge as it stood ten years ago. It may, therefore, appear superfluous at so near a date to offer another review of the subject. Nevertheless, I venture to take this occasion to do so—finding for justification that for the botanist an examination of the question from his point of view directs his thought to some fundamental questions of plant physiology. These may presently be briefly indicated, in order to engage the attention more especially to them rather than to the numerous details available. It must be prefaced, however, that I must be permitted to use the term "tannin" to cover a possibly wide variety of allied substances presenting similar but not identical structure.

The questions which present themselves for consideration are the following:

(1) In view of its precipitating action on albuminoids it is inferred to be a protoplasmic poison. How, then, is this protoplasm protected against the action of tannin? (2) Is this substance once formed of further use, and what is its ultimate fate? Although it must be admitted at the outstart that to answer these questions is not possible at present, nevertheless I may be permitted to ask your attention to some evidence which demands consideration before answers are attempted.

It is generally believed that when tannin occurs in the living cell it is in the form of a solution in the sap vacuoles. Such vacuoles have sometimes been regarded as specific, but it is probable that tannin vacuoles are nothing more or less than ordinary vacuoles in which tannin occurs as an admixture with other solutes. With the death of the cell the tannin may be transferred to surrounding substances, as occurs during the formation of cork (Drabble and Nierenstein, 1906), and in the cortex of tannin-bearing plants (e.g., *Quercus-densiflora,* Lloyd in MS.), or it may not (Lloyd, 1916), as in many fruits and seeds. During life, however, the tannin is strictly impounded by the surface layer of protoplasm limiting the vacuole, as shown long ago by Hugo de Vries (1885). What, then, is the mechanism by which the tannin is thus confined? This question demands more insistently to be answered than, I think, in the case of innocuous or admittedly metabolically useful substances—such as sugar and so forth—because of the fact that it is regarded by many as a protoplasmic poison. It is true that some organisms can procure the fermentation of tannic acid (Knudson, 1913, p. 165) and can make use of it as food. But Cook, Taubenhaus and Wilson (1911, 1915) have shown that a large number of parasitic fungi are retarded in growth by rather low concentrations of this substance: namely, from 0.1 to 0.8 per cent. Saprophytic forms exhibit more resistance —a conclusion supported by Knudson. However, precisely wherein the supposed toxicity of tannin consists is somewhat more difficult to answer. So far as I am aware, there have been few sustained attempts to discover the facts. One suggestion which may be made is that tannic acid has the power of inactivating enzymes (Katz, 1898; Knudson l.c. p. 191). If this should be generally true—as seems not improbable—we should find in tannin a substance capable of disturbing or inhibiting cell metabolism and thus indirectly throwing the machinery out of gear. It will be seen that this could occur without any direct action upon the protoplasm whatever.

It has, however, been insistently argued (e.g., more recently by de Dominicis, 1919) that the toxicity of tannin lies in its precipitating power on albuminoids. It is easy to say that the tannin is confined to the cell sap, but this statement not only assumes a semi-permeability on the part of the protoplasm toward the tannin (an explanation which might suffice if tannin were indeed non-toxic), but also the impossibility of the tannin attacking the surface layer of living protoplasm. Now, when we say that a substance is directly toxic we mean that it can in some way attack the protoplasmic mechanism; but the observed fact is that tannin is not capable of attacking the living substance directly. I am aware that there is lacking evidence to substantiate a general statement of this kind, but I may at any rate generalize to an extent sufficient to say that when tannin occurs in vacuoles and not external to the protoplast, it is incapable of attacking the surrounding protoplasm, even in high concentration. It may be objected that those cells which naturally secret tannin are as naturally immune—but this is to beg the question. The case finds analogy in the occurrence of oxalic acid in the cell. It is generally conceded that the protection of the living substance from the toxic action of this acid is insured by its neutralization to form calcium oxalate. This substance being water-insoluble is therefore innocuous Is it possible to find that the analogy is in any sense complete? Much general observation offers a negative answer, for our text-books are full of directions for the testing of tannin, based on the theory that it occurs simply as a solution. Nevertheless, it is of interest to note that some observers have experienced difficulty in getting results by the usual methods. For example, Goodlatte (1909) remarked concerning a substance which occurs in certain glands in *Parosela*: "Their contents are small pieces of hardened brown stuff, which is undoubtedly tannin but refuses to respond to any of the tests." Miss Staber (1903), studying *Sesban*, used similar phraseology in describing tannin apparently not water soluble.[1] Such experience at once suggests that there is something else present which prevents the ordinary response, and I have myself shown that this in many cases actually occurs. Thus, in certain tannin-bearing cells the reaction expected from the application of reagents which precipitate but which produce no colour reaction, do not occur; while reagents which normally produce both colour changes and precipitation produce the latter not at all, and the colour changes only slowly—often very slowly indeed. This is the case as regards the tannin cells in the pericarp of many astringent fruits, in other parts, such as leaves in the tannin-bearing barks and in many other situations where tannin occurs in the aplastic (Lloyd, 1910; Dekker, 1913) condition. On the other hand, there are many instances of the occurrence of tannin which can be precipitated with suitable reagents with more or less, generally with great, ease, as e.g., in *Spirogyra* (van Wisselingh, 1914), in many leaves (Czapek, 1911, and many others) such as those of *Dudleya Californica* (observed by myself), though we must note also that the peculiarities frequently presented by such precipitates cause us to raise the question as to their exact nature. Thus, for example, Pfeffer (1886-8) believed that albuminoid substances occur in the cell-sap of *Spirogyra* in addition to the tannin present, and believed that the precipitate obtained with methylene

[1]Dekker (1913, p. 290) points out that this difficulty was encountered by Karstens in 1857 (!) and was led to the conclusion that tannin is seldom found alone in the cell but that another substance, coaguable by alcohol, is also present.

blue is a complex of methylene blue and albumin-tannate. To this view van Wisselingh (1914, p. 177), however, takes exception, although perhaps it is not yet ascertained with certainty that the precipitate is compounded of methylene blue and tannin alone. The peculiarities of the precipitates observed by Loew (1906), both himself and in collaboration with Bokorny, presented many microchemical difficulties attributed by them to the presence of "labile albumin." Similar difficulties are presented by the "aggregations" caused in certain cells by ammonium carbonate, as first observed by Charles Darwin (1882), and by the behaviour of the tannin in the idioplasts in the cotyledons of *Quercus* (Lloyd, 1912). This difficulty is exemplified further in some cases more recently examined by myself, for example, in *Eriogonum nudum,* an herbaceous perennial of the Pacific Coast, the more superficial cells of which contain "tannin." If fresh material is placed in alcohol the tannin is extracted in considerable amount. On sectioning, however, the tannin cells are found to be unaffected so far as one can see—that is, they are quite packed with what still appears to be tannin. On the application of ammonium hydrate, however, the supposed tannin swells and breaks away from its moorings (much as in Fig. 2, 4, Pl. 2), while the cell walls, which in life show no tannin reaction, do so after treatment with alcohol. Here, then, the tannin appears to be both extracted and left behind—an obvious absurdity. What really obtains is, in my opinion, the following: Two substances are present in the vacuole of the tannin cell, the tannin itself and another substance with the physical properties of a gel. In the case of the persimmon, this second substance has been shown by E. D. Clark (1913) to be a "cellulose-like" substance which readily forms gelatinous masses with water or alkaline solutions (l.c., p. 417)—thus confirming my own earlier expressed opinion (Figs. 1-4, Pl. 2).

Again the behaviour of the tannin in the cortex and elsewhere (the distribution of which has been described by Mell, 1911) of the California tan-bark oak toward microchemical tests, is not that of tannin as such alone. Bits of bark have been kept by me for several years (since July, 1918) in alcohol. While the alcohol shows that extraction of tannin has taken place the tannin cells are still as completely filled with material as before. This material still contains tannin, but its insolubility in alcohol shows that it is not tannin alone.

The mode of occurrence of tannin is here somewhat similar to that in the cotyledons of the oak, though not identical, I believe. I have made a number of attempts to determine the exact nature of the "tannin mass," as I call it for convenience, by comparing its behaviour toward various reagents with that of tannic acid in apparently identical physical state. A mass of evidence, which is difficult to digest in brief form, has been accumulated, but for brevity's sake it is necessary to avoid too much detail. I point out, however, e.g., that the dry tannin mass, after treatment with vapour of nitrous ether, swells in cold water, dissolving only upon heating; while dry fragments of tannic acid which has been exposed as solution to nitrous ether do not swell but dissolve slowly in the cold. The behaviour of the tannin mass under this treatment, as observed microscopically, is unequivocal evidence that the tannin mass is a complex of substances, of which tannin is one, which has its own colloidal properties different from those of tannin alone. The behaviour of this substance toward the alkaloids, which are weak bases, is very similar to that observed by Loew and Bokorny (l.c.) in the tannin cells of the leaf of the rose (*Rosa*),[2] which behaviour is attributed by them to the presence of labile albumin. The same conclusions were drawn by them with respect to *Spirogyra*, but van Wisselingh denies that albumin enters into the complex. In support of the latter's opinion, I point out that I kept the material of acorn in 20% formaldehyde for several days. On examination, the tannin masses were found to be dissolved out, while the surrounding cell walls, etc., into which the tannin had diffused and by which it had been adsorbed, showed appropriate reactions. Viewed microscopically the tannin mass was found to dissolve in 40% formaldehyde. Further, after treatment with nitrous ether, the tannin mass, which is now coloured brown with an oxidation product of tannin, which fills the vacuole and which has starch grains embedded in it, fails to react to caffeine,[3] as does the untreated material. In this latter the characteristic gummy or emulsoidal compound (salt) of the alkaloid and tannin is formed, as above pointed out. It follows that the material which occupies the space of the original tannin mass, after oxidation of the tannin, is an emulsoid of probably carbohydrate nature.

The presence of a second substance is further indicated by the contrast in the behaviours of the tannin mass and flakes of dried tannin, as the following observations show:

If a saturated solution of ammonium molybdate in ammonium chloride is applied to dry tannin masses, these first absorb water and then become vacuolated.

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[2]Verbal communication accompanied by photograph.

[3]Tannic acid, after being acted upon by nitrous ether, dried and redissolved in hot water (which takes place slowly) gives no reaction with caffeine but gives a blue reaction with iron salts.

Either there may be numerous or several vacuoles, or there may be one large one. Sooner or later a small vacuole, or the large one, may burst and the expelled fluid sets as a red ppt. which takes a definite form if not too copious. A single zonation is clearly defined, beyond which a loose zone of precipitate is to be seen. Essentially the same takes place with a half-saturated solution, but more rapidly. By means of a mixture of glycerin and the reagent, the sudden expulsion of fluids may be avoided, and instead they may be expelled slowly, forming precipitation tubes and tube-like structures.

If a very weak solution of the reagent is used the tannin mass breaks up into minute globules (not in a granular precipitate) which are colourless at first, but soon take on the characteristic reaction colour.

When the reagent reaches the dry tannin flakes there is an immediate slight solution with colour. The reagent attacks the flakes slowly, etching the surface irregularly. As the etching proceeds, a coarse amorphous precipitate is formed which does not hang together or show any zonation.

If the weak solution is used no colour is seen at all, but there is gradual solution of the flakes, occupying a few minutes. No precipitate is to be seen. There is no swelling or imbibition previous to dissolving.

It is to be concluded that in the tannin mass there is another substance present which interferes with the course of the reaction.

Cells in which the tannin occurs, in association with an easily water-soluble second substance, stand in contrast with those which were described originally by Flueckiger in 1867, and later and more fully by Tichomirow (1884, 1905). I refer to the so-called "inclusions" observed by these observers in the pericarps of certain fruits (*Phoenix*, *Ceratonia*, *Diospyros*, *Acras*, etc.), and in some leaves. It is unnecessary for me to repeat what can be found in that admirable work "Lehrbuch der Pharmacologie" by Dr. A. Tschirch (1909-12) more than to repeat what that author said in 1912 concerning the tannin masses, namely, that "what they consist of is unknown;" nor is it necessary here to recount many of the details concerning these structures already presented by myself (Lloyd, 1916 and earlier). My purpose now is solely to adduce additional evidence of the presence of a second substance associated with the tannin and of the specific nature of this association: namely, that it consists in the adsorption of the tannin on the associated substance. This has in the case of the persimmon, as I have already said, been identified as a cellulose-like body (Clark l.c.). It is, at all events, a carbohydrate.

When the tannin cell reaches maturity this substance presents a sort of structure referable to that fact that it is emulsoidal. It is traversed by canals spanning stretches between more or less fusiform cavities, all extensions of superficial crevices, and the whole suggesting its origin as several separate gelatinous masses, later compacted together (Fig. 2). If the cell dies before maturation of the fruit, oxidation of the tannin content intervenes and causes red or red-brown colouration and syneresis sets in (Figs. 1, 3, 7, Pl. 1). This always happens if accidentally, or otherwise, some of the tannin cells have been burst. The emulsoid material then gushes forth into the adjoining intercellular spaces, of which on coagulation it forms a cast (Fig. 7, Pl. 1) (Lloyd, 1910, 1916). If, on the other hand, these cells are prepared for observation by setting them free in the sap of the fruit (the sap may be more or less diluted with water), the emulsoid swells, sufficiently it may be to rupture the cell wall, when a certain amount of tannin escapes. This is due to the disturbance of the adsorption equilibrium as it occurs in the fruit by the swelling of the emulsoid. The escaping tannin forms with other substances present in the sap, probably pectose, precipitation membranes which present a most bizarre variety of forms (Figs. 4, 6, Pl. 1).[4] Both the tannin masses *in situ* and the precipitation membranes answer perfectly to that item in the accepted definition of a tannin, which says that it forms an imputrescible compound with albumin, save, of course, that here albumin does not enter in. I have kept a bottle of the separated tannin masses now for over ten years in water, where they wholly retain their original character.

Although a carbohydrate gel, it differs from agar in its swelling responses to acids, bases and salts. Agar, as I have myself determined, and as amply shown by D. T. MacDougal (1921 and earlier), shows maximum swelling in water as compared with nearly all admixtures of acids, bases and salts. The tannin mass emulsoid swells less in solutions of salt than in water, more in solutions of bases and of acids and less in bases than in acid solutions.[5] Exact or even uniformly correct measurements cannot be made with satisfaction, since the cell wall always opposes itself more or less to the swelling contents, but for general comparison it will serve to point out that the tannin masses in the banana are held within relatively firm cell walls, as compared with those in the persimmon. They, nevertheless, swell in ammonium hydrate to 20 to 30 times their volume in water (Pl. 2). The swelling in acids and bases is accompanied by a greater disturbance of adsorption equilibrium than occurs in water and by a greater loss, therefore, of tannin. This is the explanation of the fact that an edible fruit may appear quite non-astringent, unless the material is held for a little while in the mouth so as to permit the action of the alkaline saliva. The nonastringency of tannin-bearing fruit at maturity is due to the adsorption equilibrium between un-

[4]I have made these observations more recently also on the tannin cells of the fruit of *Musa* (Lloyd, 1920).

[5]With regard to the last statement, I must express some doubt.

oxidized tannin and the coagulated emulsoid, and not, as recently asserted by de Dominicis (1919) on the authority of Gerber, to the oxidation of the tannin, as I have previously shown (l.c.).

The change in adsorption equilibrium, as would be expected, is related to the degree of swelling. This, in turn, depends upon the concentration of the acid or base present, as shown by the following experiment. Tannin masses taken from a very ripe fruit,[6] four days after the first wateriness had appeared, were placed in hydrochloric, sulphuric and nitric acids, each in the concentrations N/1000, N/100 and N/10, with water as control. The accompanying photograph (Pl. 3) shows the variety of response at the end of three days. Since the presence of organic acid may prevent the precipitation of the emulsoids by tannin, as in the case of tannin-albumin, we may interpret the appearances presented in the photograph by concluding that the greatest diffusion of tannin occurred in the highest concentration in which, as a matter of fact, the greatest amount of swelling occurred. It will be observed, however, that in the control there seems to be a much larger amount of diffusedly precipitated tannin. It may be that the apparently less precipitation in the concentrations N/1000 and N/100 is due not to the less escape of tannin, but to the inhibiting effect of the small amount of acid on the formation of tannin precipitation membranes; while at the higher concentration of acid, a coagulation of substances, capable of adsorbing tannin after coagulation, has taken place. However this may be, it is, I think, quite certain that the experiment definitely proves that the adsorption equilibrium is affected by the degree of swelling of the intracellular emulsoid.

The behaviour above described, variants of which have been observed, not only in the moribund cells which occur in tissues destined to die, such as those in fruit pericarps, but also in cells which take sustained part in the activity of the plant body (cotyledons, leaves, etc.), coupled with the supposed toxicity of tannin, has emboldened me to advance the theory that the protoplast, when tannin occurs, is in general protected from its toxic effect by its adsorption by another body. Were tannin a by-product only, and known to be toxic, of which, as a general statement, there is doubt, the theory would have much to recommend it. But at present the evidence is too contradictory to permit its acceptance in more than a usefully tentative way.

In the first place, a critical observer such as van Wisselingh denies the presence of an adsorbing body. His studies of *Spirogyra maxima* (1910, 1914) persuaded him that Wigand in 1862 had come to the correct conclusion, namely, that tannin is an essential factor in plant metabolism and that physiologically it is a link in the carbohydrate chain of events leading to the building up of the cell wall.

Van Wisselingh's experiments in *Spirogyra* would deserve more than mere mention, if time and space permitted. The results are in

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[6]Persimmon of the variety "Zengi."

entire accord with my observations of the behaviour of tannin in the developing embryo and endosperm of the date (*Phoenix dactylifera*, 1910) and with my interpretation of them. It is pertinent here to point out the fact that aplastic tannin, which occurs in the pericarp and integuments, differs wholly from the plastic tannin seen in the actively growing tissues of the endosperm, in that the former become fixed by adsorption in the manner above indicated; while the latter, when the fruit is preserved in copper salts, diffuses from the sap and becomes distributed in the immediate vicinity (Hillhouse, 1887, p. 14)—that is, I have found no evidence that there is a second substance to which the tannin is gathered by adsorption. The situation in which the plastic tannin is found, however, and its behaviour and final disappearance with the maturation of the fruit, and the facts observed by van Wisselingh in *Spirogyra*, all speak for its usefulness in the metabolism of the plant and, in my opinion, in the way suggested by Wigand, followed by van Wisselingh, as a factor in the process of building up cellulose.

That tannins, widely distributed though they are, are not universal, has no weight as an objection, since even starch is not universal, and of the function of starch there is no doubt. That they so often occur as excreta is equally without merit as an objection. We are well aware that excortication of the stem tissues which bear all manner of stuffs, useful and otherwise—as e.g., in *Hevea Braziliensis*, and in *Parthenium argentatum* (Lloyd, 1911)—is a clumsy method of getting rid of the useless, if this is indeed the significance to be attached to it.

In the face of the above evidence may we consider tannin as a protoplasmic poison, as e.g., de Dominicis (l.c.) insists? We cannot attach much weight to this view, as he (and not he alone) proceeds on the inference that since tannin coagulates albumin it must be toxic to protoplasm. While attributing to tannin some degree of usefulness in the economy of the plant this author regards it only as a source of energy, small in amount, because of its ready oxidizability, a suggestion also advanced by Hillhouse (1887). In answer we have to recognize that tannin is toxic to some plants, as I have already pointed out, but to some plants certain constituents of others are also toxic. The evidence on this score is therefore weak. So far as I am aware, there has been little *ad hoc* experimentation on this subject. Further, it must be admitted that if toxic, it may still be held in the sap at concentrations below a lower limit of toxicity. It is true that tannin occurs in high concentrations, as e.g., in the cortex of the chestnut of Europe up to 14% of the dry weight (de

Dominicis, 1919) or at even higher concentrations (for which Dekker, 1913, gives full statistics). But I am inclined to think that when this is the case the containing cells are to be found in tissues which are on the road to necrosis. In such cells the tannin accumulates toward a maximum and probably does not again enter as a factor in the metabolism of the plant. It may be true that tannin in some plant products may have a discouraging, not to say a depressing, effect on marauding rats or snails or such like cattle; but with teleological interpretations I am not here concerned.

It must not be lightly overlooked that other substances than an emulsoid may, by some form of antagonism, produce the effect of preventing the protoplasm from adsorbing the tannin, should it be shown that the latter is toxic. It is evident, e.g., that sugars may bear some such relation (Hillhouse, 1887, p. 22; Knudson l.c.). The theory which I have advanced is applicable no matter what substance may be found to have the power of binding tannin sufficiently to inhibit its attack upon protoplasm. Here we must also point out that toxicity and metabolic usefulness are not mutually exclusive. Tannin, though toxic, may still be one of the links in the carbohydrate chain, of which cellulose may be the last. If it should eventuate that this is true, we should be the more compelled to seek an explanation for the apparent indifference of protoplasm toward its toxicity.

In general support of the view that tannin is useful we should note that it is, in some cases, believed to be dependent upon light for its formation in leaves (see Dekker l.c.); that it disappears in the case of *Spirogyra* when kept from the light (van Wisselingh l.c.) and that it can be used as a nutrient (Knudson) by some organisms. That it furnishes little energy is of minor importance if its rôle be a necessary step in a progress of events. But I now find myself entering upon a more general phase of the discussion, in pursuing which I would only be repeating what has been very well summarized already by Dekker, van Wisselingh, and, earlier, by W. Hillhouse, a perusal of whose presidential address to the Mason College Botanical Society in 1887 reminds us that during the years intervening between them and now we have not gone very far in the solution of the tannin problem. We may take, however, a further moment to see what now may be said in answer to the questions put at the beginning of this paper.

To the first question we may answer that it is certainly known that in many cases the tannin in the vacuole is engaged in adsorption equilibrium by a second body, which has been identified for certain of these cases as a cellulose-like body. That albumin is an adsorbing body is more than doubtful, in *Spirogyra* at all events, in the light of van Wisselingh's studies; but that sugars or other substances may function in this sense remains possible.

It seems unlikely that tannin is always a protoplasmic poison for all plants. But admitting this to be the case it is not precluded from functioning in the metabolism of the plant. It seems rather more probable that in some cases tannin is toxic and in others not, and that the chemical structure correspondingly differs. In the former event the presence of a strongly adsorbing body is explicable; if the latter is the case its absence would need no explanation; weakly adsorbing bodies then permit its ready use.

As to the functions of tannin, I may first say that the plural has been used advisedly. It seems as true that some tannin is quite useless, and is merely a by-product, as that other tannin is useful. There is fairly conclusive evidence that tannin enters into the carbohydrate economy of the plant, but to say that the tannin in the pericarp could not be useful were it more fortunately situated, as one may say, may be as gratuitous as to assert the same of the sugar in a banana. Here, it is evidently a waste, but not a useless product! With Dekker we must incline to think that the usefulness of tannin lies not in serving one function alone. The effort to find a single function has probably impeded the progress of our search.

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EXPLANATION OF PLATES

Plate I. (Diospyros Kaki, "Zengi")

(Photomicrographs)

Fig. 1. A group of shrunken, dead (red) tannin cells (*t*) with four living ones at (*a*). At (*b*) the parenchyma cells are attached to the dead tannin cells.

Fig. 2. A tannin mass (colourless) by transmitted light. Canals and fusiform spaces are to be seen inside.

Fig. 3. A tannin mass which has undergone syneresis.

Figs. 4 and 6. Precipitation membranes produced on diffusion of tannin from the tannin mass into the surrounding medium which contains pectose.

Fig. 5. Section through the outer part of the pericarp, showing the distribution of tannin cells.

Fig. 7. Strands of shrunken red tannin masses (*t*) and intercellular tannin, appearing as a dark network between the parenchyma cells.

PLATE II.

(Photomicrographs)

Fig. 1. Strands of tannin cells which have been teased out from the pericarp of Musa (edible). They lie in double chains following the vascular bundles. Preparation in water.

Fig. 2. The same on the addition of weak ammonia.

Fig. 3. More highly magnified view of two adjacent tannin cells with the tannin masses slightly protruding from their ruptured adjoining ends. In water.

Fig. 4. The same preparation on the addition of ammonia. Here the gelatinous character of the swollen tannin masses is very clearly shown.

PLATE III

The different character of the precipitated tannin related to the various amounts of the tannin diffused from the associated emulsoidal masses, swollen in the acids and at the concentrations indicated on the margin of the figure. Persimmon (Diospyros Kaki) "Zengi." X 2/3.

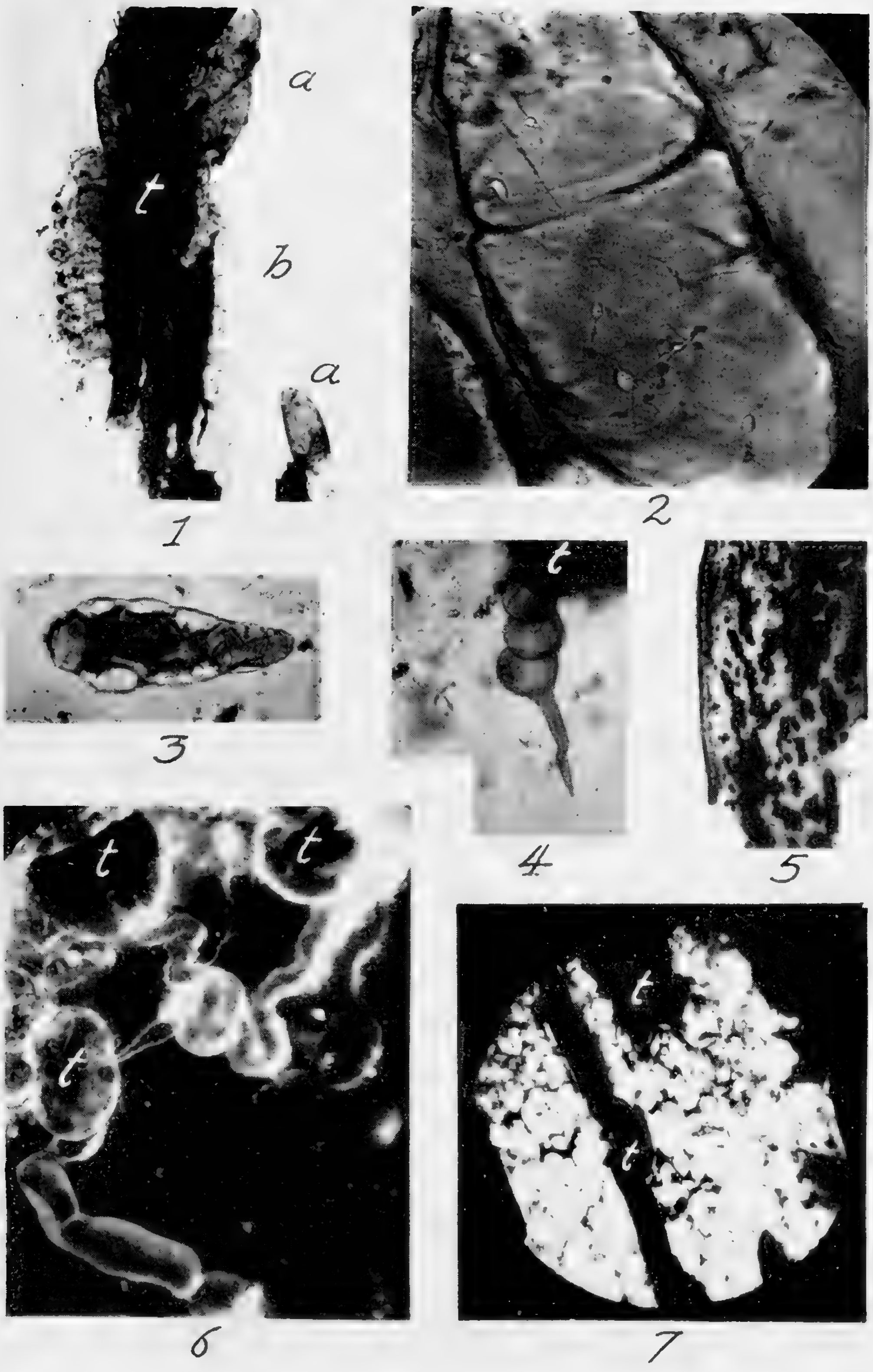

PLATE I

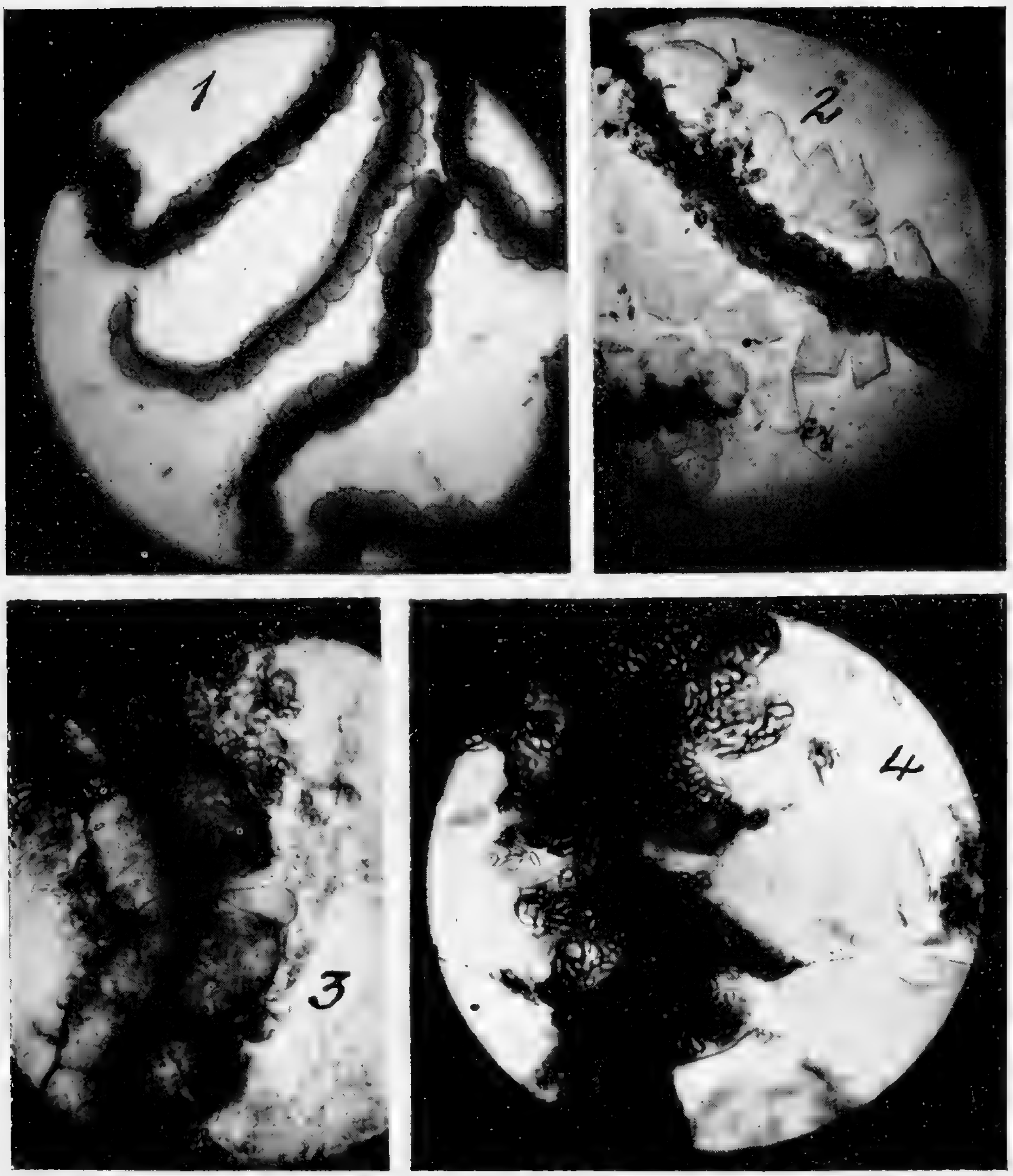

PLATE II

II. *Some Observations on the Inheritance of Awns and Hoods in Barley*

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G. G. MOE, M.Sc.

(Read May Meeting, 1922)

The Arlington barley

In the year 1912 the writer procured a small amount of Arlington barley from the Department of Agriculture at Washington, D.C. This curious type was obtained by Mr. H. B. Derr from a cross between Tennessee Winter barley, a white variety of *Hordeum vulgare* (that is, of the type commonly called six-row or four-row), and Black Arabian, a black variety of *Hordeum distichum.* After repeated selection, the type to which the name "Arlington" was given was isolated in the fifth generation from the cross. This barley is described by Mr. Derr as a six-row variety without awns or hoods, but having the disadvantage of dropping its grains very easily.

At Washington this barley was always sown in the autumn. At Ottawa, however, all kinds are sown in the spring because no barleys have shown themselves sufficiently hardy for use as winter sorts. In 1912 the Arlington was sown on April 30th and in 1913 on April 22nd—rather early for barley in this district. In both of these seasons this barley behaved as a spring variety, growing very rapidly and ripening even earlier than the ordinary six-row sorts. In 1914 the Arlington was sown on May 7th. This time it behaved as winter varieties usually do when sown in the spring: it produced only leaves until about the middle of July, when a small number of heads began to shoot out. These ripened very late. The next year, 1915, on April 26th, seed from the 1914 crop was sown and a plot was also put in, using the same seed as had been sown in 1914. Both plots behaved as early-ripening spring barley; thus showing that the remarkable conduct of the Arlington in 1914 was due either to the later sowing or to some peculiarity of the season or soil, and not to any change or mutation in the variety itself. In 1916, seeding was unavoidably late, May 13th, and the Arlington again behaved like a winter variety. In 1917, sown on May 11th it ripened very early, thus showing that rather late seeding is not in itself sufficient to cause the variety to form the winter type of plant. In 1918 it was sown, for the last time in our plots, on May 7th and again behaved as a winter variety, ripening a few heads about the middle of August, nearly a month later than the date of maturing of the full crop of heads produced in seasons when it behaved as a spring variety. Evidently the Arlington cannot be depended on to act always as a spring barley in this climate. However, nearly all the progeny obtained from crosses between the Arlington and other sorts have behaved as spring varieties.

While Mr. Derr describes the Arlington barley as beardless, the writer finds that at Ottawa it usually has awns on the two median rows of kernels. These awns may be only half an inch or less in length but are frequently much longer, especially at the edge of a plot or on plants which are isolated. But the awns are never well-developed, as in ordinary varieties. The remaining four rows (the lateral rows) of kernels are awnless. The appearance of the head is therefore very peculiar, owing to the difference—sometimes very marked—between the median and lateral rows.

Crosses between Arlington and other sorts

In 1912 some crosses were effected between the Arlington and other sorts, in order to study, among other things, the inheritance of awns and hoods when one of the parents possessed such unusual characteristics. The following were the crosses made:

Arlington (female) × 465 C (male).

Arlington (female) × 578 D (male).

Arlington (female) × 475 M (male).

The three varieties used as males are cross-bred sorts, quite fixed in character, which were produced by the writer. 465 C is a six-row variety, bearded and hulless, with green seeds. 578D is a two-row variety, hooded and hulless, with yellow seeds. 475M is a two-row variety, bearded and retaining its hull.

The cross-bred plants obtained in the first generation were as follows:

From the cross Arlington × 465C, one plant (No. 901); from the cross Arlington × 578D, fourteen plants (Nos. 902 to 909 and 922 to 927); and from the cross Arlington × 475M, twelve plants (Nos. 910 to 921).

In the first generation all the plants from each cross were essentially alike. The annexed photograph (plate A) will be of assistance in obtaining a clear idea of the appearance of the heads of these first-generation plants.

Cross No. 901

The first cross (No. 901) was between Arlington and 465C. It possessed a six-row head with well-developed awns (about three inches long) on the two median rows and with decidedly shorter and feebler awns (about one and a quarter inches long) on the four lateral rows. These heads were very brittle. The long awns of the head photographed have been somewhat broken and therefore do not show quite their full development. The interesting point about this type is that it is clearly an intermediate, so far as awns are concerned. The awns on the lateral rows may be fairly described as just half developed. They represent the middle point between the awnless condition of these rows in the Arlington and the fully awned state in the other parent, 465C. That the median rows show well-developed awns in this case is what would be expected, considering that these rows in the Arlington barley very often carry fairly well developed, though never very long, awns.

The second generation from this cross behaves as would be anticipated: it produces 50 per cent. of heterozygous plants (type III, like the first generation), 25 per cent. of the ordinary six-row, bearded type (type I, like the ancestor 465C), and 25 per cent. of the Arlington type (type II). The photograph (plate B) shows these three types together, namely, type I, six-rowed awned, type II, Arlington, and type III, the intermediate form. The head marked III in the photograph, having been very carefully preserved, shows clearly the difference in length between the fully developed awns on the median rows and the half-developed awns on the lateral rows.

It should be noted that in type I the awns on the median rows are somewhat longer and better developed than those on the lateral rows. The head marked 901S shows this very well. Yet there is a perfectly clear distinction between this condition and that found in the true type III. Seed from 901S was sown and was found to produce only fully bearded plants, thus proving that it belonged, as was supposed, to type I, although showing rather more than the usual difference in the length of the awns.

When seed is sown from these three types, types I and II breed true, while type III breaks up exactly as before. The actual numbers obtained by sowing seed of type III were as follows: Type I, 44 plants; type II, 67 plants; type III, 114 plants. These figures are rather far from the theoretical ratio of 1:1:2, but the total number of plants was small and some of them (owing to poor development or damage by wind) were very hard indeed to classify.

Cross No. 908

The second cross made was between the Arlington barley and 578D, the latter being a two-row, hooded sort. The plants of the first generation were essentially uniform. No. 908 (plate A) is one of these. This type was at first described as six-row, although the two-row condition is supposed to be dominant. As a matter of fact these heads are almost perfectly six-row in type; the median rows being, of course, entirely filled, and the lateral rows showing only a few gaps, chiefly at the base. These heads are certainly far more of the six-row than of the two-row type. The median rows carry rudimentary hoods while the lateral rows are without any trace of hoods. In subsequent generations the heads of this heterozygous type showed marked variations in the number of kernels developed in the lateral rows, and in the degree of development of the hoods on the median rows. Sometimes the number of kernels in the lateral rows varied considerably in different heads from the same plant.

When seeds from No. 908 (and others of the same pedigree) were sown, four main types were produced (see plates C and D).

Type I, two-row, with no awns, but with two rows of hoods.

Type II, six-row or approximately six-row, with no awns, but with hoods (usually very poorly developed) on the two median rows only. The lateral rows often lack two or three kernels, and occasionally more.

Type III, two-row, with well developed awns on the median rows. Occasionally a few kernels are present in the lateral rows.

Type IV, Arlington type (or similar to Arlington), six-row, with poorly developed awns on the median rows, the lateral rows being strictly or nearly awnless. As in the case of type II, two or three kernels are often wanting in the lateral rows, and sometimes the number of gaps is greater.

When the progeny of cross No. 908 and others of the same parentage were being studied most of the plants seemed to belong, definitely, to one or other of the four groups just mentioned. There were a few, however, which quite defied classification. But, when studied numerically, the grouping adopted proved inadequate to explain the proportions of each type found, there being far more six-row plants present (types II and IV) than were to be expected. The number of plants belonging to each type was counted as accurately as possible, with the knowledge available at the time, and the following figures were obtained:

Type I, 420 plants.

Type II, 997 plants.

Type III, 127 plants.

Type IV, 477 plants.

From a Mendelian point of view these figures seem inexplicable at first sight. Careful study of several generations of the progeny of these plants, however, gave some light on the problem. When seed was sown from plants of each of the four types, as described above, the following results were obtained:

Type I was found to be fixed so far as the number of rows was concerned, but, as was to be expected, it sometimes proved heterozygous in regard to awns. Some plants produced uniform progeny, while others gave groups in which representatives of type III occurred. In many cases a few kernels were found in the four lateral rows but not enough as a rule to cause confusion as to the type of the plant. Yet in at least two instances plants of six-row type were found among the progeny of a plant which had been assigned to this group, proving the difficulty of accurate classification.

Type II. Some plants bred true, others produced types II and IV, others gave types II and I, and others produced all four types. It is clear, therefore, that in the first classification we had grouped under the one type not only the true six-row plants, but also those which might be described as pseudo six-row—like the original plants of the first generation. These very often show an almost perfect development of the six rows. Evidently they are really intermediates.

Type III bred true always. When extra kernels were present in the lateral rows the progeny usually showed about the same number of these.

Type IV either bred true or else produced types IV and III. Further study revealed the fact that this type, like type II, consisted of true six-row plants (Arlington type) and pseudo six-row plants which often very closely resembled the Arlington type but which never showed full development of the kernels in the lateral rows.

The difference between the perfectly developed six-row condition and that which was somewhat incomplete (as shown by some of the plants grouped under types II and IV) was often so slight that it escaped notice when the original classification was made. That it was a vital difference was, however, clearly demonstrated in succeeding years, for it was found that whenever the six rows of kernels were fully developed the plant was homozygous in regard to rows, but if even a very few kernels were lacking at the base of the head such plants were heterozygous. The six-row condition was nearly, but never completely, dominant. These facts are of special interest in view of the generally accepted idea that the two-row condition is essentially dominant over the six-row.

With this new information, let us further study our types so as to clearly understand what inheritance ratios may be expected.

Type I contains:

(A) Two-row plants homozygous for hoods. These plants breed true to the same type.

(B) Two-row plants in which awns are recessive. These plants produce types I(A), I(B) and III.

Type II contains:

(A) True six-row plants, homozygous for hoods. These plants breed true, of course.

(B) True six-row plants in which awns are recessive. These plants produce types II(A), II(B) and IV(A).

(C) Pseudo six-row plants, homozygous for hoods. These plants produce types I(A), II(A) and II(C).

(D) Pseudo six-row plants in which awns are recessive. These plants give rise to all the types, namely, I(A), I(B), II(A), II(B), 'II(C), II(D), III, IV(A) and IV(B).

Type III is simple and always breeds true.

Type IV contains:

(A) The true Arlington type (six-row with poorly developed awns on the median rows only). These plants breed true.

(B) The pseudo Arlington type (the four lateral rows having a few gaps, usually at the base of the head). These plants produce types III, IV(A) and IV(B).

We are now in a position to reconsider the numerical ratios recorded above. In the light of the further information available we see that the ratios between the four types should be 3:9:1:3 when the plants of the second generation are counted. Taking the number of plants of type III as our unit (127) we should expect 381 plants of type I, instead of 420 observed, 381 plants of type IV, instead of 477 observed, and 1143 plants of type II, instead of 997 observed. The discrepancies are very large. It must be noted, however, that types I and II were not always reasonably easy to distinguish, for some plants had about half of the kernels developed in the lateral rows and could not be classified with certainty. Probably too many of the doubtful cases were assigned to type I. Further, it was often extremely difficult to differentiate type II from type IV, because frequently the hoods of the latter were not actually developed, though perhaps one or two slight indications of hoods might have been found by examining all the heads on the plant. When the classification was made it was supposed that any six-row plant which did not plainly show hoods on the median rows must be of the Arlington type; but this supposition was later shown to be incorrect. No doubt many plants were put down as belonging to type IV which should have been classed as type II.

We have, therefore, a satisfactory explanation of the abnormally large numbers obtained for types I and IV. If we subtract from these figures the excess over the theoretical number 381 we have 135 plants to transfer to type II, making the total of this latter 1132 plants instead of 1143 which would be predicted. This is a sufficiently close agreement to be acceptable.

A few additional observations should be made in regard to the inheritance of hoods in the group of plants we are now considering. Plants belonging to type I were very seldom abnormal. They usually carried well developed, unmistakable hoods, though sometimes these hoods were borne on awns of varying length. Plants of type II, however, showed great variations. As the Arlington barley has no awns on the lateral rows, and as the awns on the median rows are not fully developed, one naturally looked for a corresponding condition when a hooded type, otherwise similar to the Arlington, was produced. Many of the plants fell in exactly with the preconceived ideas, that is to say, they had no hoods at all on the lateral rows but carried imperfectly developed hoods on the median rows. Very rarely, plants were found which showed traces of hoods on the lateral rows in addition to very evident hoods on the median rows. But many very curious, exceptional plants were observed in which, though they did not show the normal development of awns for the Arlington type, the expected traces of hoods were lacking. At first these practically awnless plants were classified as of the Arlington type—for the degree of development of the awns in that type varies considerably. When their progeny were studied, however, occasional plants were discovered which carried a few abortive hoods, while others showed a moderate development of awns—quite different from the condition of the parent. Clearly there was a splitting up into types II and IV. The parent plants in these cases must, therefore, have been really of type II(B), in spite of the absence of hoods. Long study of these plants revealed many different degrees of development of the hoods. At the one end of the series are found plants in which the hoods on the median rows, though somewhat rudimentary, are perfectly distinct. Next come plants with only a few rudimentary hoods (perhaps half a dozen to a head) then others with only one or two to a head, then others with only one on every second or third head, then others where on the several heads of one plant only one slight indication of an abortive hood is found (often merely a little sideways bending of the tip of the very short awn) and, finally, we have those where not a single indication of a hood can be discovered, but where an occasional abortive hood can be found among the progeny. In none of these cases is the normal, partial development of the awns, characteristic of the median rows of the Arlington barley, observed. These plants must be regarded as potentially hooded, even though all trace of hoods be absent.

One other interesting fact remains to be mentioned in this connection. In some cases, where no indications of hoods could be found on any of the rows of kernels, clearly defined, though rudimentary, hoods appeared at the tips of some of the basal bracts. In rare instances there were traces of hoods on the two median rows and also, at the same time, on the basal bracts; but as a rule the presence of hoods in the one place seemed to exclude them from the other. Some two-row hooded plants (type I) were found which carried traces of hoods on the basal bracts as well, but none of the two-row plants ever lacked well developed hoods on the median rows. The "potentially hooded" condition was observed in six-row plants only. It is worthy of note that as a rule the plants of which the progeny were studied transmitted their own particular degree of development of awns or hoods to most of their descendants, though occasional variations were observed.

Plates C and D show typical heads of the four types produced when seed from No. 908 and other plants of the first generation from the same parentage was sown. The photographs also show a number of exceptional heads, the progeny of which had to be studied before trustworthy classification could be made.

903G. A study of the progeny of this plant showed that it belongs to type II(C), as it is heterozygous for rows but homozygous for hoods. It lacks many kernels in the lateral rows and must be considered as really an intermediate. It shows rather more of a six-row than of a two-row development.

908P. This plant was shown by its progeny to belong to type II(D). The four lateral rows are not well filled. This plant produced progeny of all four types.

903H. This belongs to type II(C) and is really an intermediate so far as rows are concerned. Its progeny belonged to types I and II.

924T. This plant belongs to type II(B), as it produced types II and IV. However, most of the heads on the parent plant had no trace of hoods at all. The progeny, as far as they belonged to type II, were studied with much care. Out of 26 plants, 4 carried very slight traces of hoods on some of the basal bracts. The other 22 plants had no sign of hoods anywhere. These are striking instances of the "potentially hooded" condition.

903F. This is another example of a potentially hooded plant. It had only two (abortive) hoods on the whole plant. It proved to belong to type II(B), giving types II and IV only in its progeny. The hoods on the plants belonging to type II were very scarce, but were more numerous than on the parent.

902H. This proved to belong to type III (two-row bearded) though it carries several extra kernels. Its progeny were not quite uniform but always had some extra kernels. The number of these varied from 6 to 17 to the head.

908L. This also is of type III, and carries one or two extra kernels on each head The next generation gave some plants which were free from these extra kernels, while others closely followed the parent.

908M. This shows the regular form of type III, the lateral rows having no kernels at all

The central head in plate D belongs to type IV. It is a small but typical Arlington head, as far as awns are concerned, but the lateral rows of kernels are incomplete. It no doubt belongs to type IV(B).

924S. This belongs to type IV and shows how well developed the awns sometimes are. The lateral rows are almost full of kernels. Seeds sown from this plant produced types III and IV, showing that it belongs to type IV(B).

905F. This plant was found, by a study of its progeny, to belong to type IV(B), although the awns are unusually well developed for this type. The longer awns and the gaps in the rows are sufficient proof that this is really a heterozygous form and not the true Arlington type.

The right-hand head on this plate belongs to type IV(A), and is a typical Arlington head. As the lateral rows are quite filled with kernels this plant will breed true to the one type.

A comparison between 902H and 908L on the one hand and 924S and 905F on the other hand will demonstrate how difficult it is to distinguish, by the eye, between types III and IV.

Plate E shows two magnified heads which carry hoods (more or less developed) at the tips of the basal bracts. The head marked S belongs to type II. One or two traces of hoods are seen on the median row in addition to those situated on the basal bracts. The head marked T belongs to type I. The photograph shows clearly the great development of hoods usually occurring in this type. Some of the basal bracts carry indications of hoods—a very unusual feature in plants of type I.

Cross No. 910

The third cross was made between Arlington (female) and 475M (male). The latter is a two-row bearded sort which retains its hull. A head taken from a plant of the first generation is shown in the photograph as No. 910. All the plants of this parentage had rather long heads which must be described as six-row, however much one might wish to support the belief in the dominance of the two-row state. But these heads are longer and narrower than most six-row varieties. The awns on the median rows are two inches or more in length, while the four lateral rows are awnless.

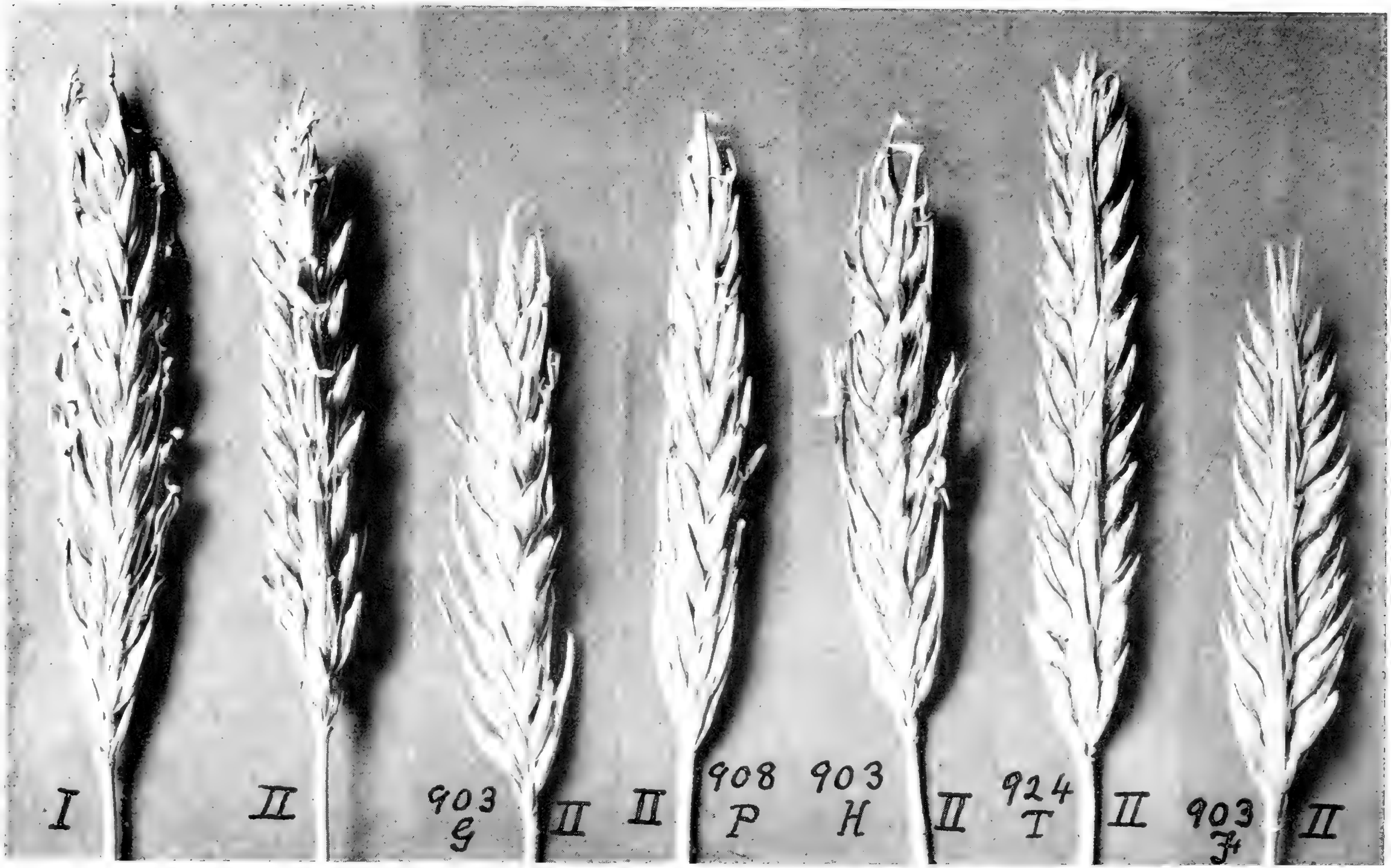
When seeds from these plants were sown, two types were obtained: type I with only two rows of kernels and strongly awned, and type II resembling rather closely the parent plant. More critical examination, and a study of the progeny of type II, revealed the fact that this case is similar to the one above related. There are here really two kinds of plants, one a heterozygous form practically identical with the parent, designated as type II(A) and the other a homozygous form marked type II(B), which is indistinguishable from the original Arlington. As a rule the lateral rows in type II(A) are so well filled with kernels that one is tempted to say that the six-row condition is dominant. But there is always a slight incompleteness in these rows at the base of the head, showing that perfect dominance does not occur. This type is characterized also by a development of the awns intermediate between that of type I and of the Arlington barley, type II(B).

The photograph (plate F) shows typical heads of types I, II(A) and II(B). The difference in length of awns is very clear and one can also see two empty glumes at the base of the head of II(A), while the head II(B) is completely filled.

As in the group of crosses studied above, heads were found in this group which, though carrying quite a number of kernels in the lateral rows, bred true. These had to be classed as belonging to type I, though the difference between type II(A) and these abnormal members of type I was very slight. The development of the awns

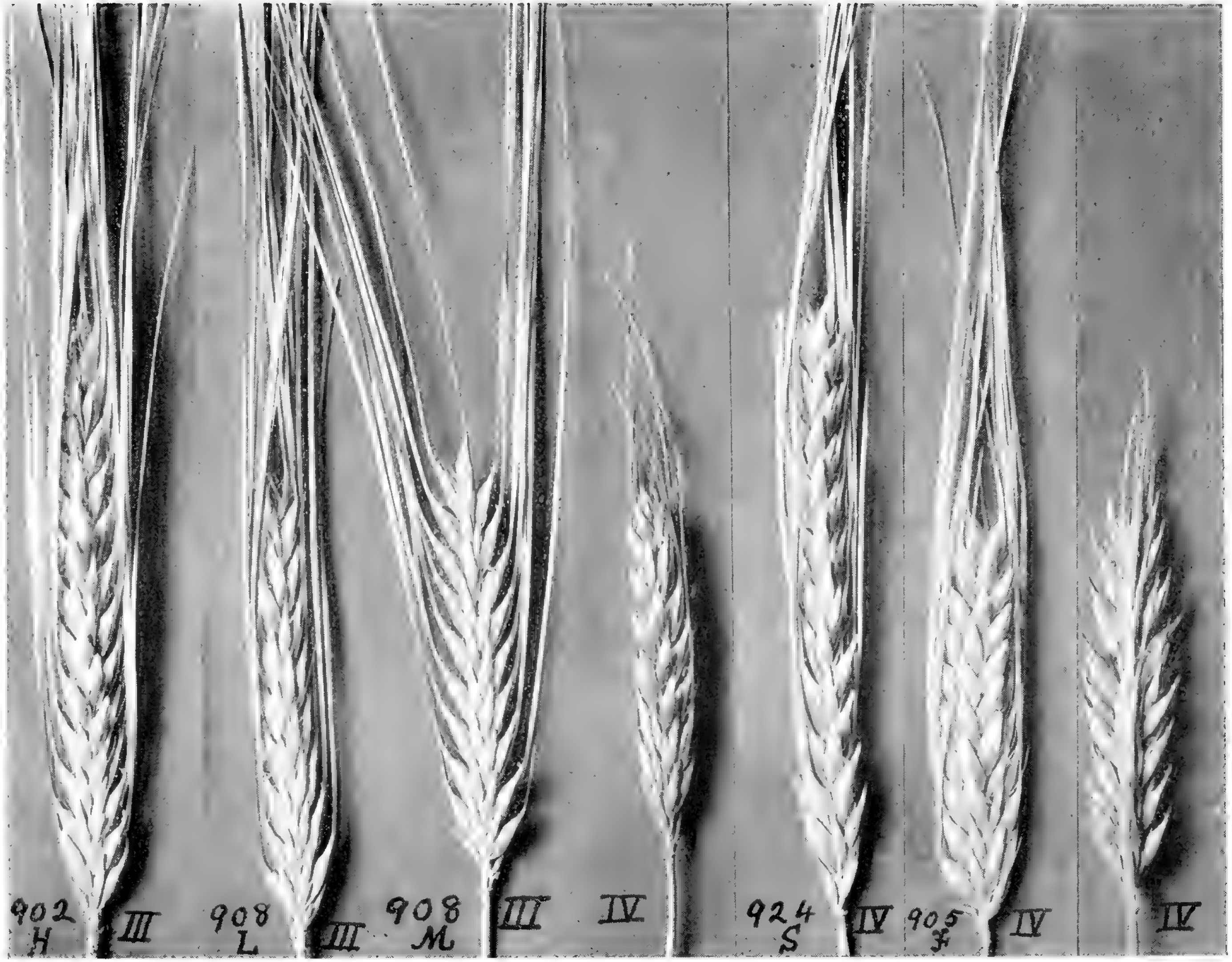
PLATE A

PLATE B



Progeny of 908 and others of the same parentage

PLATE C



Progeny of 908 and others of the same parentage

PLATE D

PLATE E

could generally be depended upon as a trustworthy indication, but this fact was not discovered until after some years of study.

The number of plants belonging to the two types was counted in some of the groups in the second generation. The totals obtained were, 70 plants of type I and 249 of type II. This is not very close to the expected ratio of 1:3, but the difficulty of classification was very great, almost all possible kinds of intermediate forms being present, some of which could not have been placed without a study of their progeny.

Colour of Kernel

As two of the parents used in the above crosses were hulless, one having yellow and the other green kernels, it was hoped to study successfully the inheritance of these colours. A great deal of work was done with very little result. It appears that one or more intermediate shades may be produced. The great difficulty in this investigation lies in the effects of weathering and diseases. In unfavourable seasons colours sometimes become so dull that they cannot be identified. Such studies should be taken up under greenhouse conditions or in a dry climate, with irrigation.

Summary

The points of chief interest brought out in this paper are as follows:

The existence is proved of a well-defined, heterozygous type of six-row barley, intermediate, in regard to awns, between the fully awned condition and the Arlington type.

It is proved that awnless types of six-row barley exist in which hoods are practically absent and which must nevertheless be classified as potentially hooded, because they fail to produce any awned descendants and because among their progeny an occasional trace of an abortive hood can be found, either in its normal position on the glume or else on one of the basal bracts.

It is shown that the six-row condition in barley is sometimes almost completely dominant over the two-row state in the heterozygous plants.

Practical Results

On account of the extreme brittleness of the heads of most varieties of which Arlington is one parent, it is doubtful whether any types of commercial value will be found among the crosses mentioned in this paper. It should be noted, however, that, in so far as the absence of awns is concerned, those six-row sorts which show abortive hoods on the median rows (or which are here classed as potentially hooded) are almost ideal. Farmers would certainly welcome the introduction of a good, prolific barley of that type. Even if the brittleness of the heads should prevent their cultivation for the ripened grain, these barleys may perhaps be useful for hay.

Some of the most promising derivatives of the crosses above discussed are being grown for further study on the Central Experimental Farm at Ottawa.

III. *The Preparation of Pancreatic Extracts containing Insulin*

By F. G. BANTING, M.C., M.B., C. H. BEST, M.A., J. B. COLLIP, Ph.D., and J. J. R. MACLEOD, M.B., F.R.S.C.

(Read May Meeting, 1922)

1. *The Preparation of the Earlier Extracts* (F. G. BANTING and C. H. BEST)

In two previous papers a brief outline of the preparation of pancreatic extracts has been given. Active anti-diabetic extracts of degenerated gland, exhausted gland, foetal gland, and finally adult beef gland, were made. The main problem in the preparation was to get rid of or avoid the presence of proteolytic enzymes.

The first extract used was obtained by ligating the pancreatic ducts of the dog, and waiting from seven to ten weeks for degeneration of the acinar tissue. The remnant, which contained healthy insular tissue, was removed and macerated in ice-cold Ringer solution. By this procedure a non-toxic extract which markedly reduced the blood sugar and the excretion of sugar in diabetic dogs was obtained in small quantity. Active extract was also prepared from the pancreas of a dog that had been injected with secretin.

The foetal calf extract was at first made by macerating pancreas of foetal calves of under four months development in Ringer's solution and filtering. Later, 95 per cent. alcohol was used in place of Ringer's solution.

The alcoholic filtrate was evaporated to dryness in a warm air current and the resin-like residue redissolved in saline. This solution when injected subcutaneously or intravenously into a diabetic dog caused a marked fall in blood sugar and in sugar excreted in the urine. It was further found that this extract did not contain trypsin, that it was destroyed by boiling, that the active principal was insoluble in 95 per cent. alcohol and that daily injections enabled a totally depancreatized dog to live a much longer time (70 days) than has hitherto been recorded after such an operation.

Potent extracts of the whole gland of the adult ox were obtained in a similar manner, using equal volumes of 95 per cent. alcohol and pancreas, with the exception that the alcohol was made 0.2 per cent. acid by the addition of HC1. It was found that the fatty substances in the extract could be removed by washing twice with toluol without deterioration of the potency of the extract. The alcohol could also be removed by distillation in vacuo at low temperature and it was found by reducing the volume to one-fifth instead of to dryness that a watery extract of the active principal was obtained. This could be sterilized by passing it through a Berkfeld filter. The extract in this form was given to a human diabetic and results in every way comparable to those obtained on the depancreatized dog were observed. However, owing to the high percentage of protein also present, sterile abcesses formed in a few instances at the site of injection.

2. *The Preparation of the Extracts as used in the first Clinical Cases* (J. B. Collip)

The demonstration by Banting and Best that extracts of pancreas, prepared with certain precautions, contain a substance having the power to lower the blood sugar and to raise the sugar tolerance in diabetes, both in dogs and man, warranted an attempt to isolate this substance in a sufficiently pure state for repeated subcutaneous or intravenous administration in man. The problem was to remove most of the protein and salts and all of the lipoid material from the extracts without destroying the active principle. In the endeavour to solve this problem various methods were tried and the following was found to be most satisfactory.

To a small volume of 95 per cent. ethyl alcohol freshly minced pancreas was added in equal amount. The mixture was allowed to stand for a few hours with occasional shaking. It was then strained through cheese cloth and the liquid portion at once filtered. The filtrate was treated with two volumes of 95 per cent. ethyl alcohol. It was found by this treatment that the major part of the protein was removed while the active principle remained in alcoholic solution. After allowing some hours for the protein precipitation to be effected the mixture was filtered and the filtrate concentrated to small bulk by distillation in vacuo at a low temperature (18° to 30°C). The lipoid substances were then removed by twice extracting with sulphuric ether in a separating funnel and the watery solution returned to the vacuum still, where it was further concentrated till it was of a pasty consistency. 80 per cent. ethyl alcohol was then added and the mixture centrifuged. After centrifuging, four distinct layers were manifested in the tube. The uppermost was perfectly clear and consisted of alcohol holding all the active principle in solution. Below this, in order, were a flocculent layer of protein, a second clear watery layer saturated with salt and a lowermost layer consisting of crystals of salt. The alcohol layer was removed by means of a pipette and was at once delivered into several volumes of 95 per cent. alcohol, or better, of absolute alcohol. It was found that this final treatment with alcohol of high grade caused the precipitation of the active principle along with adherent substances. Some hours after this final precipitation the precipitate was caught on a Buchner funnel, dissolved in distilled water and then concentrated to the desired degree by use of the vacuum still. It was then passed through a Berkfeld filter, sterility tests made and the final product delivered to the clinic.

The essential points relating to the extract prepared as outlined above are:

(1) It contains only a minimum of protein.

(2) It is practically salt free and can readily be made isotonic.

(3) It is lipoid free.

(4) It is almost free from alcohol soluble constituents.

(5) It can be administered subcutaneously without fear of any local reaction.

IV. *The Effect of Insulin on Normal Rabbits and on Rabbits rendered Hyperglycaemic in Various Ways*

By F. G. BANTING, M.C., M.B., C. H. BEST, M.A., J. B. COLLIP, Ph.D., J. J. R. MACLEOD, M B., Ch.B., F.R.S.C., and E. C. NOBLE, M.A.

(Read May Meeting, 1922)

The successful demonstration of the beneficial influence of insulin in the diabetes of depancreated animals raised in our minds the question whether it would also affect the blood sugar of normal animals and of those made diabetic in other ways than by pancreatectomy. If such were the case a ready means would be at hand by which to test the activity of the extracts at various stages in their production. In the present communication we record briefly results bearing on these two questions.

1. *The Effect of Insulin on Normal Rabbits.*

In over 150 normal rabbits, fed with oats and sometimes also with sugar, the percentage of sugar in blood from the marginal ear vein was determined, before and at various intervals following subcutaneous injections of insulin. The average percentage of sugar in 90 of these rabbits prior to the injections was 0.133 with a maximum of 0.186 and a minimum of 0.095 (Schaffer-Hartman method). A marked fall from the initial values was observed to occur within an hour or so of the injection and for purposes of physiological assay we have come to designate as one rabbit dose the amount of insulin (given subcutaneously) which lowers the blood-sugar by 50 per cent. in 1-3 hours. This method of evaluation of the potency of insulin seems to be fairly satisfactory, for we have found that relatively greater effects in reducing the blood sugar, are obtained when the same extract is used on diabetic dogs. Thus, 10 c.c. of a certain extract injected into a rabbit reduced the blood sugar from 0.135 to 0.071 in 1½hours, after which it began to rise again, whereas 20 c.c. of the same extract given to a diabetic dog weighing about five times more than the rabbit caused the blood sugar to fall from 0.375 to 0.030 in 7 hours. The lowest percentage of blood sugar observed in rabbits treated with insulin was 0.01 in 2 hours 45 minutes after the injection. The purer the preparation of insulin used the more rapid is the fall in blood sugar. The fall seems to be equally rapid in well-fed and starving animals.

Some time after the injection of insulin the rabbits often show characteristic symptoms. A preliminary period of hyperexcitability gives place to a comatose condition in which the animal lies on its side, breathing rapidly (often periodically) with sluggish conjunctival reflex and widely dilated pupils (rectal temperature normal). On the slightest stimulation, as shaking of the floor, violent clonic convulsions supervene in which the animal either throws itself over and over, or lies on its side with head markedly retracted and the limbs moving rapidly as in running. These convulsive seizures usually last 1-2 minutes, and they often come on without any apparent stimulation, when the interval between them is about 15 minutes. They frequently terminate in death from respiratory failure.

Out of a total of 123 rabbits receiving insulin convulsions were observed in 26 cases, and the maximum percentage of blood sugar at which they occurred was 0.047 (except in one animal in which 0.067 was found), and the minimum percentage at which there were no convulsions was 0.037.

This close parallelism between the percentage of blood sugar and the incidence of convulsions suggests that a causal relationship exists between the two. This view is supported by the observations of F. C. Mann on dogs rendered hypoglycaemic by removal of the liver from the circulation (Proc. Amer. Physiol. Soc. Dec., 1920), and by the fact that we have found that subcutaneous injection of dextrose (4 gms. in 20 per cent. solution) restores the animal to the normal condition within a few minutes of the injection. Occasionally recovery may ensue without injections of dextrose, but this is rare. The animals restored by dextrose may subsequently relapse into convulsions which can again be removed by dextrose. Injections of saline solutions or of pentose sugars have no effect.

2. *The Effect of Insulin on Hyperglycaemic Animals.*

For these experiments the rabbits were fed on oats and sugar so as to ensure an abundant accumulation of glycogen in the liver. Portions of liver were also removed after death for determination of glycogen.

The methods employed to cause hyperglycaemia were asphyxia, carbon monoxide poisoning, injection of epinephrine (adrenalin) piqûre and ether. Having satisfied ourselves, by at least four observations in each group, that the above methods cause marked hyperglycaemia in untreated rabbits we then repeated them on rabbits previously injected with insulin. In every case we found in the injected animals either that there was no rise whatsoever in the percentage of blood sugar or that the rise was very markedly less than in untreated animals. The following results giving the percentages of blood sugar will illustrate.

(*a*) PIQÛRE

Time	*Uninjected Rabbit*	*Time*	*Rabbit Injected with Insulin*
10.15	0.137	12.50	0.123
11.00	Piqûre	3.30	Insulin
11.30	0.305	4.30	0.083
12.05	0.420	4.45	Piqûre
12.50	0.457	5.15	0.081
2.20	0.386	5.20	Insulin
3.20	0.244	6.00	0.064
4.25	0.187	6.30	0.093
....	.....	8.15	0.045

(*b*) EPINEPHRINE

Time	*Uninjected Rabbit*	*Time*	*Rabbit Injected with Insulin*
9.15	0.154	12.00	0.159
10.20	Epinephrine	12.05	Insulin
10.55	0.364	2.00	0.040
11.30	0.397	3.05	Insulin
12.00	0.440	3.35	Epinephrine
1.00	0.440	4.00	0.040
2.05	0.410	4.30	0.057
....	.....	5.00	0.065
....	.....	5.35	0.060

(*c*) ASPHYXIA

Time	*Uninjected Rabbit*	*Time*	*Rabbit Injected with Insulin*
9.50	0.140	9.50	0.124
9.55	Asphyxia (20 min.)	10.00	Insulin
10.23	0.383	11.00	0.077
10.55	0.376	2.00	Insulin
11.25	0.370	2.20	0.045 (hyperexcitable)
11.55	0.222	2.22	Asphyxia (20 minutes)
12.25	0.200	2.45	0.159
.....	.....	3.15	0.075
.....	.....	3.45	0.046

V. *The Effect Produced on the Respiratory Quotient by Injections of Insulin*

By F. G. BANTING, M.B., C. H. BEST, M.A., J. B. COLLIP, Ph. D., J. HEPBURN, M.B., and J. J. R. MACLEOD, M.B., Ch.B., F.R.S.C.

(Read May Meeting, 1922)

It is generally recognized that the most satisfactory evidence of the utilization of carbohydrate in the animal body is afforded by the behaviour of the respiratory quotient, *i.e.*, the ratio between the volume of CO_2 expired and of O_2 absorbed. In the normal animal this quotient approaches unity in proportion as carbohydrates replace fats and proteins in the total metabolism; thus, when sugar is given to the animals that are starving or living on a fat and protein diet the quotient promptly rises. In the completely diabetic animal on the other hand, whether this condition be brought about by removal of the pancreas, by administration of phloridzin or by disease, the quotient remains at the level of about 0.7 (which is characteristic of the metabolism of a mixture of fat and protein) even when large amounts of carbohydrate are ingested.

At an early stage in our work on the influence of insulin on diabetes it became necessary to observe this quotient. This has been done on a case of severe diabetes in man and on several depancreated dogs. The patient (aet. 29) (Dr. G.) has been suffering from diabetes for six years. During the past few months his diet has contained approximately 10 gms. carbohydrate with total calories of 1200. The total daily excretion of sugar has been 15-30 gms., the blood sugar between 0.28 and 0.33 per cent. and acetone bodies always present On February 17th, 1922, while on the above diet, the R.Q. was found to be 0.74 and it remained unchanged in several observations made during the succeeding two hours. Insulin (4 c.c.) was then injected subcutaneously and 20 gm. cane sugar was taken by mouth with the result that the quotient rose to 0.90 in two hours. In a second observation of the same type, but in which only 2 c.c. of insulin was injected, the quotient rose to 0.82 in about three hours. Results of a similar character were obtained by Dr. W. R. Campbell on two other diabetic patients in the medical clinic of the University.

The observations on depancreated dogs were carried out by placing a closely fitting mask over the head and connecting it through two-way valves and wide-bore tubing with a spirometer. There was no great difficulty in training the animal to lie quietly on his side during the observation and great care was taken to see that there were no leaks around the edges of the mask.

The usual procedure was to determine the quotient several times, then to administer cane sugar or pure dextrose either by mouth or subcutaneously, with or without injections of insulin and then to observe the quotient at frequent intervals. Observations have so far been made on five animals, at periods varying from 48 hours to 154 hours after the pancreatectomy. We are aware that several observers have found that the depancreated animal still retains, for 4-5 days, some power to utilize carbohydrate as shown by a small rise in the quotient when sugar is ingested. This, however, does not detract at all from the value of our results.

The following are the most significant results:

Dog II.—Before pancreatectomy, R.Q., after 22-23 hours starvation was 0.85 and 0.86. 30 gms. sucrose by mouth caused it to rise to 1.0 in 35 minutes and it remained exactly at this level for 2 hours. The animal was then depancreated (Jan. 21st) and the R.Q., 48 hours later (Jan. 23rd), was 0.63 rising to 0.76-0.78 in 1½ hours after 20 gms, sucrose. In 74 hours (10.46 a.m.) after pancreatectomy 25 gms. sucrose (by mouth) and 10 c.c. insulin, subcutaneously, caused the quotient to rise to 0.86 in 31 minutes and 0.90 in 1½ hours; it then fell to 0.77 in 3-3½ hours. The animal was again given 20 gms. sucrose and 8 c.c. insulin at 3.15 p.m. and the R.Q. rose within 50 minutes to 0.91 then to 0.94 (1 hr. 37 min.), 0.93 (3 hrs. 17 min.) and 0.87 (4 hrs. 1 min.). Next morning (25th) R.Q. stood at 0.68 and 20 gms. sucrose raised it to 0.82 (3 observations) and 0.85 (1 observation). On the 26th, R.Q. was 0.68-0.72; 20 gms. sucrose raised it to 0.81 in 1 hour, and 10 c.c. insulin 5 hours later caused it to rise to 0.90 in 40 minutes.

The earlier results of this experiment are not entirely convincing because there was a definite increase in R.Q. with sucrose alone. This may be because sufficient time had not elapsed since the pancreatectomy for the power to utilize carbohydrates (especially laevulose) to disappear. The observations on Jan. 26th, five days after the pancreatectomy are more satisfactory.

Dog III.—R.Q. 0.65 (49 hrs. after pancreatectomy); after 7 c.c. insulin subcutaneously (without sucrose) it rose to 0.70 (1 hr. 34 min.), 0.68 (1 hr. 51 min.) and 0.67 (2 hr. 7 min.). 20 gms. sucrose, given orally, 5 hours after the insulin caused the quotient to rise to 0.89-0.86.

A repetition of this experiment on the next day raised R.Q. to 1.06.

Dog IV.—R.Q. 0.63 (48 hrs. after pancreatectomy); after 25 gms. sucrose it rose to 0.70 (in 52 min.) returning to 0.65 in 1 hr. 35 minutes. Two days later 5 c.c. insulin followed in 1½ hours by 30 gms. sucrose caused the quotient to rise to 0.83 in about 1 hour after the sucrose. On Feb. 20th, six days after pancreatectomy, this animal was fed sugar *ad lib.* 10 c.c. of insulin then caused R.Q. to rise from 0.76 (on the previous day) to 0.95.

Dog V.—Sucrose caused a decided rise in R.Q., from 0.67 to 0.81, in 51 hours and a smaller rise (from 0.69 to 0.73) in 107 hours. On the sixth day 8 gms. dextrose was injected subcutaneously along with 10 c.c. insulin only raised R.Q. from 0.73 to 0.80.

Dog VI.—This animal was not depancreated but was starved for three days. It was given 4 c.c. insulin subcutaneously with the result that R.Q. rose from 0.77 and 0.75 to 0.90 (in 42 minutes after injection) and then fell to 0.85 (in 1 hour 6 minutes) and 0.78 (in 1 hour 36 minutes).

Although the above observations were not as adequately controlled as we should have desired, they show conclusively that insulin given along with sugar to depancreated dogs raises the Respiratory Quotient to a much higher level than occurs with sugar alone.

VI. *The Effect of Insulin on the Percentage Amounts of Fat and Glycogen in the Liver and Other Organs of Diabetic Animals*

By F. G. BANTING, M.B., C. H. BEST, M.A., J. B. COLLIP, Ph.D., J. J. R. MACLEOD, M.B., Ch.B., F.R.S.C. and E. C. NOBLE, M.A.

(Read May Meeting, 1922)

I. *Glycogen in the Liver, Heart and Muscles*

(*a*) *Liver.*—Minkowski found that after total extirpation of the pancreas in dogs, the percentage of glycogen in the liver fell to 0.5 or less even when large quantities of dextrose had been ingested. When laevulose was given (in three cases) considerably larger amounts of glycogen were deposited (0.72 to 8.14). Several investigators have confirmed these observations except that Cruickshank has found that laevulose also does not form glycogen provided the extirpation of the pancreas is complete. He infers that Minkowski's results with laevulose were due to the fact that all pancreatic tissue had not been removed.

In two depancreated dogs which were given large quantities of cane sugar for several days preceding death we found in the liver 0.044-0.047 per cent. in the one, and 1.29-1.35 per cent. of glycogen in the other.

Very different results were obtained when insulin, as well as sugar, was given to depancreated dogs for a few days before the animal was killed. Thus, in one animal (Jan. 3rd) 13.27 per cent., in another (Feb. 21st) 12.58 per cent. and in a third (March 28th) 11. 4 per cent. of glycogen were found in the liver. These striking differences indicate that one effect of insulin is to stimulate the glycogenetic function of the liver and this fact, coupled with the knowledge that it also raises the respiratory quotient in an hour or two after it is given subcutaneously, lends support to the hypothesis that carbohydrate can be utilized in the body only after it has been converted into glycogen.

In two other cases less striking results were obtained, namely, 2.85 per cent. in one (Jan. 14th) and 4.9 per cent. in another (April 2). In one animal that took sucrose very greedily and to whom large doses of insulin were given during the two days preceding death considerably more than 12 per cent. of glycogen was found in the liver.

(*b*) *Heart and Muscles.*—Cruickshank found that the glycogen in the hearts of 6 normal dogs averaged 0.5 per cent. the maximum being 0.85. In 16 depancreated dogs the average was 0.7; in one case it was 1.05 per cent. Macleod and Prendergast found in two normal dogs that the glycogen in the ventricle is increased by starvation to 1.00 and 1.05 per cent. respectively. In the present investigation, 0.79-0.92 per cent. and 0.98 per cent. glycogen were found respectively in the hearts of two depancreated dogs fed sugar but receiving no insulin. In four other depancreated animals to whom insulin was given, as well as sugar, the values were 0.725, 0.600, 0.570 and 0.296. These few observations indicate that insulin reduces the glycogen percentage in the heart of diabetic animals to within the normal limits.

With regard to the skeletal muscles, nothing conclusive can as yet be said although there is some indication that insulin causes the percentage of glycogen to increase (cf. table).

II. *Total Fatty Acid in Liver, Heart and Blood*

Fat.—This has been determined as fatty acid by Leathes modification of the Kumagawa-Sato method with the following results, the animals in all cases being given large amounts of sugar.

Without insulin	No.	Liver	Heart	Blood
	48	12.25	4.26	....
	50	14.10	2.59	1.21
	51	9.90	....	1.12

Although much larger percentages of fat than these have been observed to occur in the liver after phosphorus or phloridzin it is nevertheless much above the average for laboratory animals, which is given by Leathes as about 4-6 per cent. With regard to the blood our results compare with those given by Bloor for severe diabetes viz., 1.01 per cent. These values were decidedly altered in animals, receiving insulin thus:

No.	Liver	Heart	Blood
52	7.425	3.00	(1) 0.333
			(2) 0.270
55	2.190	2.08	0.531
56	4.410	....	....

There were two dogs, however, in which the liver fat was not found to be reduced following insulin. In both of these (53 and 54) excessive doses of insulin were given so that the one animal (53) died during the night and the other (54) in the forenoon following the administration. In the former case 10.276 per cent. and in the latter 26.360 per cent. of fatty acid were found in the liver.

The results so far obtained on the fat of blood show insulin to have a decided reducing effect.

The observations taken as a whole show that insulin given to sugar-fed diabetic animals causes the fat to become reduced in the liver at the same time as glycogen accumulates. Whether glycogen would also accumulate in this organ without ingestion of sugar, we cannot at present say. It is clear that there must be a stage following the administration of insulin when glycogen and fat both are present in considerable percentage in the liver. This is shown in experiment 56. The protocolls of these experiments are given in abbreviated form in Table I.

References

Cruickshank, E. W. H. Jour. Physiol. 1913, xlvii, p. 1.
Macleod, J. J. R. and Prendergast, D. Trans. Roy. Soc. Can., 1921, Sec. V, p. 37.

TABLE I

No.	Date		Total Fatty Acid (per cent.)			Glycogen-dextrose							
	Oper.	p.m.	Liver	Heart	Blood	Liver	Muscle	Heart	Sugar	Insulin	R.Q.	Sugar Blood	Diabetes Remarks and Evidence of
41	11/14	II/21	..	....	....	12.58	0.38	0.725	Yes	Yes 17th-21st	0.63	....	R.Q. rose from 0.63 to 0.70 after sugar. R.Q. rose to 0.78, 0.79 and 0.83 after sugar and insulin.
48	III/3	III/9	12.25	4.26	....	....	....	....	Yes	No	0.64	0.3 0.35	Dog died during night.
49	III/3	III/14	....	....	....	0.047 0.044	0.58 0.48	0.918 0.787	Yes	No	0.65 0.67	....	R.Q. before sugar 0.65, 0.65. after sugar 0.67, 0.67.
50	III/14	III/18	14.10	2.59	1.207	....	....	....	Yes	No	0.63 0.69	....	Died during night. R.Q. before sugar 0.63, 0.63. after sugar 0.66, 0.65. 0.67, 0.69.
50	III/18	III/25	9.90	....	1.121	1.354 1.287	0.034 0.034	0.98 0.98	Yes	No	..	....	Took large amounts sugar for 3 days before death. R.Q. before sugar 0.67-0.68. after sugar 0.67, 0.67, 0.67.
52	IV/8	IV/14	7.425	3.00	0.333[1] 0.270[2]	....	....	....	Yes	Yes on 13th	....	0.31[1] 0.030[3]	[1]Fat and sugar of blood on IV/12 while on diet of meat and biscuit. [2]Fat in blood on IV/13 after which large dose insulin. [3]Sugar in blood when moribund.
54	IV/19	IV/22	26.350 26.375	3.00	0.368	0.34	....	....	No	Yes on 21st	....	0.305	Fed meat and biscuit. Large dose insulin given on 21st and moribund on 22nd.
53	IV/19	IV/22	10.276	....	....	....	....	....	No	Yes on 21st	....	0.33	Same as 54, only died during night.
C_1	I/10	I/14	....	....	....	2.567 2.845	0.41	0.600	Yes	Yes on 14th	....	....	Animal in very poor condition at time of death.
C_2	....	XII/22	....	....	....	Over 12	0.600	....	Yes	Yes 20th-22nd	....	....	
55	IV/25	IV/28	2.189	2.08	0.531	11.4	0.764	0.570	Yes dextrose	Yes 26th-28th	0.62-.64 0.67[1] 0.85[2]	0.30 {0.105 0.111}	[1]After dextrose. [2]After dextrose and insulin. Dog in good condition at time of death.
56	IV/27	V/2	4.410	....	....	{4.92 4.70 4.78}	....	.293 .299	Yes dextrose	Yes (1st)	..	.396 .410	Dog dead but not cold when liver was removed for glycogen.

VII. *The Effect of Insulin on the Excretion of Ketone Bodies by the Diabetic Dog*

By F. G. BANTING, M.B., C. H. BEST, M.A., J. B. COLLIP, Ph.D., and J. J. R. MACLEOD, M.B., Ch.B., F.R.S.C.

(Read May Meeting, 1922)

As the production and excretion of ketone bodies is one of the cardinal symptoms of the diabetic individual the effect of the administration of extracts of pancreas containing the active principle of the gland (insulin) upon the excretion of these substances by depancreated dogs was studied. This study was initiated before a purified extract was produced. The extracts used were made by alcoholic extraction of the whole gland of the ox, the alcohol being subsequently removed by vacuum distillation. They had a fair degree of potency but contained considerable protein, lipoid and salt and were relatively very crude as compared with later products. The results obtained, however, show in a very striking manner the influence upon the excretion of ketone bodies, a fact which has subsequently been confirmed on clinical cases (cf. Canadian Medical Association Journal, March, 1922).

The animals used were depancreated and placed in metabolism cages. The urine was collected over twenty-four hours periods and the total excretion of ketone bodies determined by the method of Van Slyke.[1] When a very definite ketonuria had developed extract was administered by subcutaneous injection.

The results are shown in the accompanying table:

[1]Van Slyke, D.D., Jour. Biol. Chem., 1917, 32, 455.

Excretion of Sugar and Ketone Bodies in Depancreated Dogs

No.	Date	Whether Insulin given	Urine Volume	Total Dextrose Excretion	Total Acetone Bodies	Remarks
			c.c.	gms.	mg.	
I	Dec. 14	No insulin	1,000	..	75	♂ wt. 15 Kg.
	" 15	"	885	24	62	
	" 16	"	1,150	36	80	
	" 17	"	1,000	25	60	
	" 18	"	750	27	....	
	" 19	"	850	29	190	Nitrogen 1.14.
	" 20	"	800	28	210	Nitrogen 1.15 Blood sugar 0.309% Blood sugar following insulin {0.217%, 0.085%, 0.051%}
	" 21	insulin	600	none	none	
II	Jan. 6	no insulin	1,000	29.7	100	
	" 7	"	375	28.4	187	Blood sugar 0.351%
	p.m.	insulin	...	....	....	Lowered blood sugar to 0.085%
	Jan. 8	no insulin	425	4.25	none	
	" 9	"	325	9.95	none	
	" 10	"	370	9.6	none	
	" 11	"	275	25.2	34	
	" 12	"	325	25.4	55	
	" 13	"	750	18.0	114	
	p.m.	insulin				
	Jan. 14	"	600	8.0	none	
III	Jan. 13	no insulin	750	22.4	206	♀ wt. 5 Kg.
	" 14	"	1,750	63	3.141	Blood sugar 0.295%.
	p.m.	insulin	500	30	none	Insulin given at 9 a.m. Dog killed at 4.30 p.m.

The most convincing of these experiments is number two in which administration of insulin on one day, January 7th, caused the acetone bodies to disappear from the urine of the next three days, during which no insulin was given. After this they again gradually appeared to be removed a second time by injection of insulin.

VIII. *The Bog-Forests of Lake Memphremagog: Their Destruction and Consequent Successions in Relation to Water Levels*

By F. E. LLOYD, M.A., F.R.S.C., and G. W. SCARTH, M.A.

(Read May Meeting, 1922)

The very extensive destruction of bog forest which is to be seen fringing the lakes in the Eastern Townships region of Quebec province, is naturally ascribed to the erection of dams at the outlets. But a study of the conditions at Lake Memphremagog in particular shows that this is not the only factor, nor, in this case at least, the most important one.

Descriptive.—The two chief localities—viz,. the mouth of Cherry river at the north end of the lake and the mouth of Barton and other rivers entering the south end—include many hundreds of acres of dead and moribund trees. The bare or scantily foliaged trunks that still stand amid a new vegetation of lower growth and totally different character are but a small remnant of a former dense growth, as is proved by the greater number of uprooted and fallen trees. Evidently there existed at one time a climax bog forest, the dominant species being tamarack (*Larix laricina*)[1] and cedar (*Thuja occidentalis*) with frequent spruce (*Picea mariana*) and a few large pines (*Pinus strobus*). Besides the destruction of the trees, however, a great change must have taken place in the forest floor; for instead of the typical continuous, gently undulating surface, the ground is broken and uneven. Durable structures, such as roots and logs, retain around them portions of the old forest floor, but even these are generally more or less undermined, while the intervening spaces have sunk to a much lower level. The soil in the depressions is no longer the fibrous "raw humus" of a forest floor but a fine black "muck."

The new vegetation which flourishes amid the ruins of the old is naturally varied on so uneven a substratum. It varies both locally and over whole areas with relation to the summer level of the water-table, ranging from aquatic almost to mesophytic.

The lower levels of a drainage system are occupied by extensive beds of *Typha*. Here the destruction of trees and forest floor has been very great, only stumps remaining as a rule to testify to their former existence. The same applies to areas occupied by bog shrubs (*Chamaedaphne, Myrica, Spiraea, Cephalanthus*).

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[1]Nomenclature according to Gray: New Manual etc., 7th ed.

Over the greater part of the area, however, the dominant new growth consists of an upper stratum (20 ft. high, or less) of thrifty black ash (*Fraxinus niger*) and swamp maple (*Acer rubrum*), with an undergrowth of shrubs (*Alnus incana, Ilex verticillata, Salix* and *Cornus spp.*) and a bottom stratum that varies with the level of the depression from limnophytic forms, such as *Typha, Alisma, Sagittaria, Carex, Eleocharis,* etc., to mesophytic types—asters, *Chelone, Heuchera,* grasses and mosses.

Water levels.—The water table in August, 1921, was found to be 1¼ to 2¼ ft. below the present level of the old forest floor. Observations elsewhere and records by Burns (1911, 115-121) show that this is more than sufficient elevation for a tamarack or cedar bog-forest. The lake level at the same time was about 680 feet above sea level (falling later to a still lower level). The remains of old forest floor ranges from 682.5′ to over 684′, and while the large trees at these levels are either dead or dying, there are healthy cedar saplings at 682.5′, spruce at 682.8′, and pine at 683′. The advantage possessed by these young trees is simply that their smaller spread of roots enables them to find sufficient substratum on the hummocks of old forest floor that still persist. Conversely, the cause of injury to the older trees is apparently the erosion or decay of their original root-run, and not an excessively high water level during the growing season.

The present normal level of spring floods, however (probably about 683′), is sufficient to submerge the greater part of the old forest floor, and there is evidence of still higher floods about 30 years ago. Coastal erosion can be proved to have been much greater than then now. While flooding during the dormant period does not directly injure trees in swamps, it has probably done so indirectly through destruction of the peaty floor. This may have been brought about partly by actual suspension and washing out of material and partly by effecting increased decomposition and shrinkage of the organic matter. Regular inundation with lime containing water must diminish soil acidity, and since the high spring level is accompanied by a low summer level, oxidation (eremacausis) is favoured (see Transeau, 1905-6, p. 371). It is significant that the new vegetation is hydrophtic rather than oxylophytic. The present character of the peaty floor also suggests advanced decomposition.

Rate of tree growth.—A study of the trees that still survive enable us to trace the progress of untoward conditions in these bog-forests. The general age of renewal shoots (orthotropous lateral shoots produced after death of original branches) is about 30 years as a rule, suggesting a climax of destruction about that date; but measurements of annual rings in a large number of tree trunks of all ages gives a complete and graphic record of the struggle with environment. The method was to measure the radial increase in 10 year periods, taking an average radius, or, if necessary, more than one, in each tree. Error due to variation with age is largely eliminated by the greatly differing ages of the trees.

Tree growth in Barton and Cherry River swamps.—Average radial increment in millimeters of coniferous trees (8 tamaracks, 8 cedars, and 1 pine), of ages varying from 30 to 300 years, and of ash trees (40 to 130 years old) during ten year periods ending:

	1841	1851	1861	1871	1881	1891	1901	1911	1921
Coniferae..........	18	19	18	16	14	13.6	6.9	3.7	2.7
Ash...............	9	9	7.0	6.3	5.0	6.6	4.7	3.7	4.9

It will be seen from the table that the rate of growth began to fall off about 70 years ago and fell most rapidly about 30 years ago—*i.e.*, at the same time that (from evidence of coastal erosion) the spring floods were at a maximum. The decrease has slowed down since then in the case of coniferae in general, and has even been followed by an increase in the case of ash trees.

Cause of the destruction.—A comparison with the dates of erection of the various dams at Magog (1834, 1882 and 1914), while it does not eliminate the possibility of the 1882 dam having some effect, strongly indicates some other agency, especially since, as we have seen, it is the flood level and not the summer level that is, or has been, excessively high.

Precipitation records of the past 45 years[2] yield no evidence of any marked correspondence between either the total annual fall or the effective winter plus spring precipitation and tree growth.

There remains the factor of deforestation, assisted by artificial drainage, which is well known to cause increased seasonal fluctuations in the levels of stream and lake. The curve of tree growth harmonizes well with the probable rate of removal of the forest covering,[3] at first gradual, reaching a climax over 30 years ago, and more recently balanced by new growth.

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[2]McGill University records, and also Richmond, Que., as far as available.

[3]No actual records being available, we take general opinion from various sources at its face value.

It is almost impossible in this part of the country to find a lake of any size that has not been dammed, but Deer lake, the best example studied, furnished evidence of similar progressive destruction. Coulter (1904, pp. 46-48 and plate 6) and Transeau (1905, p. 371) describe destruction of bog-forest that might be attributed to the same agency.

The peculiar effect of increased fluctuation of water level upon the floor of bog-forest has not, to our knowledge, hitherto been described. Land surface and summer water-table approximate as a result not of raising of the latter but of lowering of the former.

The normal succession from hydrosere to xerosere is thus reversed. At first, no doubt, there has to be destruction of the close canopy of forest before the most photophilous forms can enter, but, thereafter, as the forest floor subsides, the more hydrophilous types of undergrowth gradually supplant the less. Thus, *Typha* encroaches on formations that normally encroach on it. It is difficult to describe this as other than a retrogression. As the vegetation covering becomes denser, affording greater protection, the process may tend to slow down, and no doubt a turning point is reached.

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IX. *River-bank and Beach Vegetation of the St. Lawrence River below Montreal in Relation to Water-levels*

By FRANCIS E. LLOYD, M.A., F.R.S.C., and GEORGE W. SCARTH, M.A.

(Read May Meeting, 1922)

The subject matter of this paper formed part of the evidence in an important legal test case hinging on the question as to the position of high water mark of the St. Lawrence River in the vicinity of the locality here described, viz., the beach below the Imperial Oil Works, near Point aux Trembles, below Montreal. The practical difficulty of determining water levels along a river front is increased by the great variation in range of fluctuation due to local differences of topography, so that a standard range of measurements at one place cannot be applied to another. Nature, however, has provided a series of vegetative zones which, while they may vary in width and vertical range from place to place, always retain their relative positions, and serve everywhere as a natural graduated scale from which to read off not only average high water mark, but all the other seasonal levels also. To classify all the minor topographical variations in this zonal series would require an extended investigation, but a preliminary study of other localities enables us to state that the series here described is of very wide application and the variations from it apply generally to minor details.

The river was very low at the time (18 Sept., 1921) the measurements were taken. The tension line between the beach vegetation and that of the dry land was placed at eleven feet above the water surface at that time, corresponding to the figure of 24′ on the scale at the Lachine canal (assuming that the range of difference between high and low water is the same at the two stations). The close turf formation ends abruptly at this level, which is near the foot of the river bank. It corresponds with the upper limit of *Salix longifolia*[1] as a close formation, only straggling bushes extending further. The occurrence of numerous oil marks (due to floating oil) on branches and stones confirm the view that here the water level remains stationary for some time.

The beach vegetation at this station may be divided into four major zones:

[1]Nomenclature according to Gray: New Manual etc., 7th ed.

Characteristic dominant plants	*Elevation above water level* (18 Sept., 1921)
1. *Salix longifolia*	2.5 to 10.9 ft.
2. *Scirpus fluviatilis*	2.0 " 3.8 "
3. *Butomus umbellatus and Sagittaria heterophylla*	1.0 " 1.7 "
4. *Vallisneria spiralis*	−4(?) " 0.5 "

(Correction: +13.2′ = reading on Lachine canal scale.)[2]

Whereas the first two zones overlap, the others do not meet. The intervening space between 2 and 3 is occupied by various annuals, such as *Cyperus esculentus*, *Bidens frondosa* and *Polygonum spp.*, not having any ecological relation to water level. That between 3 and 4 is an open formation with scattered *Butomus umbellatus*,[3] *Sagittaria*, and *Alisma*. The *Salix longifolia* zone is quite typical of the St. Lawrence beaches. It is about the only shrubby form that successfully meets the rigorous ecological conditions of seasonal submersion by water and mauling by ice. Three characteristic plants accompany the *Salix* in the lower half of its range *Polygomum emersum* (hairy in the upper levels, smooth in the lower), *Spartina Michauxiana*, and *Lythrum salicaria*. In some other localities *Spartina* forms a distinct zone between that of *Salix* and *Scirpus*; here it occurs only as isolated clumps.

Other species abundant in the Salix zone are cocklebur (*Xanthium oviforme*) and silverweed (*Potentilla anserina*). These have an ecological relation to the water levels which need not be here discussed. But the presence of other common forms, such as *Vicia cracca* and *Desmodium* with *Cuscuta* is probably fortuitous.

In Zone 2. *Scirpus fluviatilis* is accompanied by *S. americanus*, which has a slightly lower range.

The dominant species of Zone 3 have also a slightly different optimum, *Butomus* predominating above, *Sagittaria* below. The rapid spread of *Butomus* so recently introduced is noteworthy.

The fourth zone is almost pure *Vallisneria*.

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[2]Lachine canal scale reading for 17 Sept., 13.1′; for 19 Sept., 13.3′, Montreal Harbour Commission.

[3]Thoroughly established in this locality.

X. *A Study of Induced Changes in Form of the Chloroplasts of Spirogyra and Mougeotia*

By G. W. SCARTH, M.A.

(Read May Meeting, 1922)

That the chloroplasts of *Spirogyra* under certain conditions undergo remarkable changes in form is not a new observation. De Vries,[1] for example, figured and described many shapes seen by him in natural, untreated, but evidently somewhat pathological material; Loew[2] made use of the changes as an indicator of certain toxic action; Osterhout[3] noted contraction under the action of barium and strontium chlorides, regarding it as a specific response (which it is far from being); Chien[4] extended it to cerium salts but only for one species; while Lloyd, in his Introductory course in General Physiology,[9] has set the study of these and other behaviours of the cell as an exercise for students. The nature and meaning of the phenomenon has never been adequately studied, however, although an understanding of it would explain that much is obscure in protoplasmic movement in general. It is believed that the following observations throw some light on the physico-chemical actions underlying this manifestation of so-called irritability of protoplasm.

The biological material. All the species procurable of *Spirogyra* exhibited the changes to be described. The size and unusual complexity of form of the chloroplasts in this genus render them particularly suitable for study, but similar changes have been observed by the writer in the allied genus *Mougeotia*, in mosses and in higher plants. Since in the phenomenon to be described, plasticity is one of the features shown by the chloroplasts, it is necessary to find out whether normally they are fluid bodies. If so, their shape (viz. spirally coiled ribbons with usually a lobed or sinuous outline) is a very unstable one and must undergo change. It has not been possible to detect the slightest modification of outline under ordinary conditions of temperature, etc., even after many hours of watching. That slow amoeboid movements *may* occur in response to certain natural stimuli is quite possible. Indeed, it is well known that the flat chloroplastic band of *Mougeotia* slowly orients itself with regard to light, while those of higher plants also change position and are said to be amoeboid. That in the case of *Spirogyra* the chloroplasts are not normally fluid is proved by other than the above merely negative observation. When the cells are plasmolysed it is common to find some whose chloroplasts are too rigid to contract with the cytoplasm but maintain their position more or less, while the cytoplasm is pulled in between the coils. The spiral form itself I take to be an expression of elasticity, being the position of minimum curvature, and so of least resistance, for an elastic body confined in a closed cylinder shorter than itself. Thus in species whose chloroplasts are no longer than the cell they are straight and longitudinal, the more their length exceeds that of the cell the closer the spiral. From all these considerations it would seem that under ordinary conditions the physical state of the chloroplasts is that of an elastic gel.[5]

The changes in form.—The "contraction" which is observed in abnormal chloroplasts is not a simple phenomenon but is of two very different types. In type I the body behaves as a liquid and the contraction is manifestly an endeavour to assume minimal area. The sinuosities of margin first smooth out, the whole chloroplast thickens and shortens, becomes cylindrical and finally spherical, or else constricts into several spheres. During the longitudinal contraction the coils may slip round the plasmatic layer if the spiral is loose; if it is tight they usually contract across the vacuole to one side of the cell, pulling films of protoplasm with them. If more than one chloroplast is present they may become tightly twisted like a rope before they have time to uncoil. The phenomenon is not always so simple of explanation—contraction may begin before the margin smoothes out (see later). The second type resembles the first inasmuch as there is longitudinal contraction with somewhat similar results, but instead of thickening as it contracts the chloroplast becomes thinner, its margin becomes more sharply toothed than normally and vacuoles may develop around it. Progress toward minimal area does not take place. The appearance suggests a syneretic contraction of the gel, with expulsion of water. Changes in other cell structures usually accompany the above. Some of the cytoplasmic strands that support the nucleus in its median position give way, and the latter is pulled to one side of the cell by contraction of the other strands. Diminution of viscosity giving free play to the action of surface tension would explain this as well as the first type of chloroplastic change, but that the syneretic type of contraction may also take place is shown by occasional vacuolization and other evidence to be described. With certain factors (heat, etc.) the contraction of the cytoplasmic strands appears to pull the chloroplasts toward the nucleus. The same two types of behaviour are shown by the chloroplasts of other plants. *Mougeotia* resembles *Spirogyra*, allowing for the difference of initial form, while the more common ellipsoidal plastids in other plants examined may change to spherical, as in Type I, or apparently shrink, as in Type II.

Which of the above types of phenomenon may occur depends mostly on the strength of the factor employed to produce it. The first results from a mild agent, tending to pass over to the second if long applied, while a strong agent produces the second type immediately. Different species also differ in their tendency to one or the other type, while a combination of both types at the same time may also occur.

Reversibility.—Remarkable as are the changes in the appearance of a cell they are not necessarily accompanied by its death. Even in the limiting state of type I with the chloroplasts spherical and the nucleus lateral, the cell-membrane may retain its semi-permeability for a long time (as tested by eosin-staining or plasmolysis), while with less pronounced changes the cell may even recover its normal form again. This remarkable result has been established in the case at least of certain salts. For example, some filaments of *Spirogyra* were kept in M/100 barium chloride until every cell was more or less changed, from mere smoothing of the chloroplasts up to their assumption of the spherical form, most being of a cylindrical sausage-like shape. The filaments were then transferred to tap-water and examined from day to day. After about a week the cells had nearly all resumed their normal appearance, with the exception of a few that had died. The latter were mostly cells in which the chloroplastic band had beaded off into spherical bodies, and even such cells may retain their vitality for a few days. Reappearance of marginal processes is the first sign of recovery. Irregular and grotesque shapes mark the process of reversal to the spiral form.

The factors.—The specific action of the various factors that bring about changes in form is not included in the scope of this paper, but rather the features that are common to all.

A long series of eperiments has been and is still being carried out on the action of electrolytes, and the conclusions stated later were suggested by the results obtained, a fuller statement of which is postponed. An induction current produces similar changes, type I if mild, type II if strong. It is with this agent alone that rounding of the plastids of higher plants has been detected. Heat (a temperature of 45 C. immediately, and lower temperatures if the exposure is prolonged) produces both types of behaviour with a strong tendency to the second, as is also the case with other agents that coagulate albumin, such as alcohol, acetone, etc. Other toxic organic substances, such as chloroform and ether, produce changes of type II which are probably irreversible, and a result of the complex phenomena of death rather than an immediate reaction to the applied agent.

Meaning of the changes.—The discovery that electrolytes are effective in producing the changes in question in general proportion (the exceptions are explicable) to their precipitating action on colloids suggested use of the ultra-microscope to see if any such precipitation could be detected in the living protoplasm. By selecting suitable material with scanty pyrenoids one may obtain a picture in which the chloroplasts appear dead black except for a faint outline and the bright periphery of the pyrenoids. Soon after contraction sets in there appears a faint luminosity, due to specks of light, which increases as time goes on but remains slight as long as the liquid phase lasts. In the second type of contraction the luminous specks increase rapidly while faint needles of light may also be seen, resembling a much reduced picture of fibrin coagulation in blood. The whole picture represents different stages in the precipitation of an emulsoid. That it is a gel rather than a sol we are dealing with probably matters little, as the difference between them seems to lie only in the degree of approximation of the particles.[6] Precisely what happens during the precipitation of an emulsion colloid is not yet known. The first step seems to be loss of water by the highly hydrated colloidal elements. One result of this is a greater difference of refractive index of the two phases and the development of a reflecting surface—a transition from an emulsoid to a suspensoid condition, as Michaelis has described it. It may be either these dehydrated particles or agglutinations of them that give the first appearance of light in the field. A concomitant result of transference of water from internal to external phase would naturally be a lowering of viscosity, permitting the chloroplasts to change form under surface tension. Further precipitation until the particles unite may be termed coagulation and is followed by contraction of the whole body (syneresis) with expulsion of water. With some agents the cytoplasm may remain unaffected up to this stage, but later it too goes through similar phases of precipitation.

The intermediate type in which a solid contraction of the chloroplast as a gel precedes the more liquid condition, is different from type II inasmuch as no visible coagulum is formed, but may be of a similar nature if syneresis of agar is comparable to that of blood.

Applications.—R. Chambers,[7] in his micro-dissection studies, found a lowering of viscosity to immediately precede the rise that accompanies death He regarded this lowering as post mortem, but these experiments show that a similar fluid stage may be ante mortem or even reversible. Mechanical injury gives a markedly fluid effect on the chloroplasts of *Spirogyra*.

The resemblance between the movements here studied and the complex evolutions of the chromatic figure in mitosis, e.g., in the shortening and thickening of the spireme and its tendency at one stage to form a spiral suggests that a similar physico-explanation might be found for these mysterious phenomena of life. Chambers'[8] work again, in his discovery that chromosomes may be artificially produced, gives strong support to this view. But to arrive at the cause of such movements there seems to be much promise in the experimental method here adopted of treating with precipitating agents and ultra-microscopically studying the results.

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XI. *Acceleration of Growth and Regression of Organ-Hypertrophy in Young Rats after Cessation of Thyroid Feeding. The Production of Tetany in Rats by Thyroid Feeding.*

By A. T. CAMERON, F.R.S.C., and J. CARMICHAEL

(Read May Meeting, 1922)

(From the Department of Biochemistry, University of Manitoba)

When thyroid tissue is fed to young animals (rats, rabbits) the rate of growth is slowed (2) and at the same time certain body-organs (heart, liver, kidneys, adrenals, pancreas, etc.) hypertrophy, while, if the thyroid dose be sufficiently large, there is a definite slowing of the growth of the thyroid gland, which appears anaemic, and enters into a resting condition (12, 10, 2). These effects, which can be produced even in the adult rat (6), are definitely traceable to thyroxin, the essential secretion of the thyroid (3), are not produced by iodide (2), nor by parathyroid (4), nor by administration of other internally secreting glandular tissue (12), nor can they be attributed to a high protein diet (2, 4).

Hewitt has recently carried out an experiment which seemed to show that the effect on organ-hypertrophy was only temporary, and that after cessation of thyroid feeding there is a return towards normal proportions (11). As his conclusions were based on results with but five rats, and these from different litters, although these results were in good agreement, we have thought it desirable to carry out some further experiments of this nature; these were designed to ascertain in addition the effect of cessation of thyroid feeding on total growth.

During the past year we have completed six series of experiments on 43 white rats (20 males and 23 females) from six litters. In these 17 rats were used as controls, and the remainder fed thyroid.

In each series rats of the same age and sex were compared, some receiving a diet of unlimited bread and milk plus a daily dose of desiccated thyroid, based rigidly on the actual body-weight, the others, bread and milk only. We have shown elsewhere that the addition of a corresponding amount of liver or muscle tissue is without effect (2), and no such addition was made to the diet of the controls in these experiments. The thyroid was mixed to a paste with a little flour and water, and fed on a watch-glass in the morning immediately after the animals were weighed. It was usually eaten rapidly and completely. No other food was given till late in the afternoon. Food residues were almost always present in the cages next morning, indicating that excess had been given. The animals were kept in exactly similar cages a little more than one cubic foot in capacity, and under the same conditions of heating and lighting.

Two thyroid preparations were used, one a Merck-Darmstadt preparation containing 0.38 per cent. iodine, and at least 12 years old, the second an Armour hog-thyroid preparation (December, 1919) containing 0.34 per cent. iodine. These will be subsequently referred to as A and B They had been previously compared (2) and found to produce very similar results on growth and organ-hypertrophy; perhaps those produced by the former were a little greater, as is to be expected from the slightly greater iodine (and therefore presumably thyroxin) content.

The thyroid feeding was commenced in different experiments at from the 30th to the 34th day of age, continued for 18 or 19 days, and then bread and milk alone were given for from 18 to 48 days. At the conclusion of each experiment the animals were chloroformed, dissected as rapidly as possible, and the organs transferred to stoppered glass vessels and weighed.

During the experiments 7 animals died, one control female, and 3 males and 3 females during thyroid feeding. Most of the latter showed evidence of tetany. Three animals developed tetany but recovered.

Details of Experiments

Experiment 1. A litter of seven rats, two males and five females, born March 9th, 1921. One of each sex was used as control. Thyroid feeding was commenced on the 33rd day of age, and at the rate of 1:5000 of body-weight (preparation B), for rats 1, 6 and 7. Rat 4 was fed thyroxin for 8 days and subsequently thyroid; it is omitted from the record. Rat 5 was fed thyroid at the ratio of 1:2000. On the 9th day of treatment, at 3.45 p.m., this rat developed typical tetany, with rapid breathing, dragging of hind limbs, and flexion of fore-limbs. An injection of 0.5 per cent. $CaCl_2$ was given 20 minutes later, but the shock of injection brought on a marked and typical paroxysm, with very rapid breathing and tetanic spasms. The animal died 3 minutes later. Post-mortem examination of the heart showed the ventricles in systole and auricles very distended. The pupils were not contracted. The remaining animals were fed thyroid daily for 19 days, and then a normal diet for the succeeding 27 days.

Experiment 2. A litter of 6 rats, 4 males and 2 females, born September 10th. One of each sex was used as control. Thyroid feeding (1:5000; preparation A) was commenced on the 34th day of age, and continued for 18 days; subsequent normal feeding was given for 48 days. Rat 2 was found dead on the morning of the 7th day of treatment in a typical tetany posture. At autopsy rat 4 was found to be a male. The testes were high up and very small, and the animal was in poor condition. None of the rats showed marked fat-deposits. All thyroids were bright red in colour.

Experiment 3. A litter of 7 rats, 4 males and 3 females, born September 14th. Two males and one female were used as controls. Thyroid feeding (1:5000; preparation A) was commenced on the 30th day of age, and continued 18 days; subsequent normal feeding was given for 48 days. Rat 4 was found dead on the morning of the 15th day of treatment in a typical tetany position. On the afternoon of the 13th day of treatment rat 7 developed typical tetany, with rapid heart beat and respiration, dragging of hind limbs, and tremors. This attack gradually passed off, and the animal had apparently completely recovered 3 hours later. It had no subsequent attacks. At autopsy all animals showed fat-deposits, and all thyroids were bright red in colour.

Experiment 4. A litter of 7 rats, 4 males and 3 females, born December 8th, 1921. Two males and one female were used as controls. Thyroid feeding (1:5000; preparation B) was commenced on the 33rd day and lasted 19 days. Subsequent normal feeding lasted 37 days. At autopsy rat 4 (thyroid-fed) was distinctly fatter than the others. All thyroids were bright red.

Experiment 5. A litter of 7 rats, 3 males and 4 females, born December 25th. One male and 2 females were used as controls. Thyroid feeding (1:2000; preparation B) was commenced on the 30th day of age, and lasted 18 days. Subsequent normal feeding lasted 37 days. All thyroids were bright red at autopsy.

Experiment 6. A litter of 10 rats (another died before the experiment commenced) small and somewhat weak, 3 males and 7 females, born February 11th, 1922. Thyroid feeding (1:5000; preparation B) commenced on the 32nd day of age and lasted 19 days. Subsequent normal feeding lasted 18 days.

Rat 2, a control animal, was found dead on the morning of the 54th day. This animal was less than half normal weight.

Rat 4 commenced to develop tetany at 9.00 p.m. on the 7th day of treatment. Apparently no bread and milk had been eaten during the evening. At 9.55 p.m. the tetany was distinct, the animal moved clumsily, with hind limbs extended; heart beat and respiration were violent. It was tapped gently; this was followed by spasmodic jerking back of the head, and subsequent convulsions, in which the animal lying prone suddenly bounded in the air, while there were typical tetanic movements. The movements changed in type to spasmodic elevation of the hind limbs. The eyes gradually glazed. At 10.02 the animal was extended, with slow and deep respiration; it showed occasional spasmodic jerks. At 10.05 the breathing was still slower—irregular gasps. At 10.09 each respiration set up a wave-spasm which passed down from the fore-limbs (greater extension) to the hind-limbs (which were raised). One minute later the animal was dead in the typical tetanic position.

Rat 6 was found dead on the morning of the 7th day of treatment. Tetany was suspected.

Rat 7 showed onset of tetany at 5.30 p.m. on the 7th day of treatment; the heart beat was rapid and the fore-legs flexed. At 7.00 the symptoms were more marked, both heart-beat and respiration were more rapid than normal and the hind limbs were extended. At 9.00 the animal was distinctly better and feeding. There was apparently no attack on the 8th day, but a slight attack was noticed at 5.50 p.m. on the 9th day and others suspected on the morning of the 10th and afternoon of the 11th day. The animal subsequently appeared normal.

Rat 9 was found dead on the morning of the 16th day of treatment. Tetany was suspected.

Rat 10 had an attack of tetany on the morning of the 15th day of treatment with rapid heart beat and convulsions. It did not eat the thyroid dose on this day.

The animals which survived till autopsy showed bright-red thyroids in every case. Rat 7 showed no fat deposits; the others seemed normal in this respect.

The results, as far as body-growth is concerned, are shown for all rats which survived till autopsy in Table I. Those rats which died during treatment, with the exception of control 2 in experiment 6, showed no abnormal growth change when compared with those similarly treated. The weights of body-organs, calculated to percentage of total body-weight, are shown in Table II.

TABLE I

Experiment No.	1	2	3	4	5	6
Thyroid Dose 1:	5000	5000	5000	5000	2000	5000
Thyroid Preparation	B	A	A	B	B	B
Initial age (days)	33	34	30	33	30	32
Thyroid period (days)	19	18	18	19	18	19
Subsequent period (days)	27	48	48	36	37	18
Initial weight (gm.)						
Males						
Control (1)	41	46	39	31.5	35	25.5
(2)	..	..	39	37.5	..	..
Thyroid (1)	41	42	38	32	32	31
(2)	..	44	..	43.5	38	..
Females						
Control (1)	36	42	36	39	31.5	24
(2)	..	..	..	..	32.5	27
Thyroid (1)	38	41	40	41	33.5	27.5
(2)	37	..	37	34.5	35.5	26.5
GAIN IN WEIGHT						
Thyroid period (*Males*)						
Control (1) gm.	55	44.5	49.5	37.5	40.5	45.5
(2)	..	..	48.5	52.5	..	..
Thyroid (1)	25	34.5	22	38	27	14
(2)	..	13.5	..	30	35	..
Subsequent period (*Males*)						
Control (1) gm.	81	64.5	88	50.5	83	44
(2)	..	..	82.5	66.5	..	..
Thyroid (1)	78	89.5	101.5	93.5	105	20.5
(2)	..	11	..	114	93.5	..
Total gain (*Males*)						
Control (1) gm.	136	109	137.5	88	123.5	89.5
(2)	..	..	131	119	..	..
Thyroid (1)	103	124	123.5	131.5	132	34.5
(2)	..	24.5	..	144	128.5	..
Thyroid period (*Females*)						
Control (1) gm.	39	38	33	43	36	15
(2)	..	..	..	..	39.5	40.5
Thyroid (1)	30	27.5	28.5	29	28	23.5
(2)	34.5	..	26	22	28.5	11.5
Subsequent period (*Females*)						
Control (1) gm.	50	32	52	49	59.5	6.5
(2)	..	..	..	..	71	37
Thyroid (1)	72	52.5	72.5	65.5	66	26.5
(2)	56.5	..	64.5	55	64	15
Total gain (*Females*)						
Control (1) gm.	89	70	85	92	95.5	21.5
(2)	..	..	..	..	110.5	77.5
Thyroid (1)	102	80	101	94.5	94	50
(2)	91	..	90.5	77	92.5	26.5

TABLE II

Expt.	Rat No.	Sex	Treatment	Body-weight	Liver	Kidneys	Heart	Spleen	Lymph glands	Adrenals	Thyroid	Muscle	Testes
					%	%	%	%	%	%	%	%	%
1	2	M	C	173	7.0	0.99	0.40	0.257	0.067	0.021	0.0089	0.178	1.38
	1	M	T	144	6.5	1.12	0.45	0.269	0.059	0.022	0.0097	0.185	1.43
	3	F	C	125	6.3	1.13	0.47	0.282	0.093	0.032	0.0107	0.202	
	6	F	T	140	7.5	1.14	0.46	0.451	0.110	0.039	0.0109	0.189	
	7	F	T	128	7.2	1.13	0.48	0.295	0.102	0.034	0.0094	0.196	
2	1	M	C	155	5.7	0.81	0.39	0.29	0.107	0.014	0.0097	0.174	
	3	M	T	166	5.8	0.88	0.37	0.28	0.119	0.020	0.0113	0.197	
	4	M	T	68.5	8.2	1.20	0.77	0.22	0.112	0.035	0.0165	0.149	
	5	F	C	112	6.2	0.94	0.49	0.27	0.135	0.024	0.0139	0.181	
	6	F	T	121	5.9	1.01	0.44	0.21	0.081	0.027	0.0089	0.189	
3	1	M	C	176.5	5.1	0.84	0.31	0.29	0.064	0.016	0.0122	0.169	
	2	M	C	170	5.7	0.83	0.36	0.28	0.084	0.015	0.0126	0.174	
	3	M	T	161.5	5.9	0.90	0.38	0.30	0.057	0.015	0.0092	0.177	
	5	F	C	121	6.7	1.09	0.39	0.31	0.097	0.023	0.0121	0.197	
	6	F	T	141	6.3	1.06	0.46	0.30	0.101	0.023	0.0140	0.171	
	7	F	T	127.5	6.4	0.96	0.42	0.31	0.079	0.041	0.0144	0.198	
4	1	M	C	119.5	6.3	1.06	0.39	0.26	0.059	0.019	0.0118	0.187	1.39
	2	M	C	156.5	5.2	0.92	0.38	0.22	0.071	0.019	0.0133	0.172	1.57
	3	M	T	163.5	5.1	0.83	0.37	0.22	0.091	0.017	0.0091	0.181	1.27
	4	M	T	187.5	4.7	0.81	0.36	0.28	0.050	0.017	0.0091	0.188	1.19
	5	F	C	131	5.0	0.72	0.37	0.23	0.093	0.028	0.0135	0.183	
	6	F	T	135.5	5.4	0.89	0.41	0.28	0.062	0.032	0.0100	0.176	
	7	F	T	111.5	5.8	0.95	0.45	0.30	0.081	0.030	0.0138	0.190	
5	1	M	C	158.5	6.3	0.90	0.39	0.23	0.098	0.019	0.0100	0.199	1.14
	2	M	T	164	5.2	0.90	0.43	0.29	0.107	0.016	0.0103	0.185	1.18
	3	M	T	166.5	6.2	0.92	0.42	0.30	0.164	0.017	0.0095	0.194	1.15
	4	F	C	127	5.8	1.02	0.48	0.29	0.101	0.032	0.0142	0.200	
	5	F	C	145	5.9	0.98	0.44	0.26	0.124	0.028	0.0171	0.205	
	6	F	T	127.5	5.3	1.00	0.45	0.23	0.102	0.031	0.0127	0.195	
	7	F	T	128.5	6.5	1.07	0.54	0.27	0.088	0.037	0.0098	0.201	
6	8	M	C	115	6.8	1.48	0.46	0.33	0.041	0.018	0.0109	0.190	1.68
	9	M	T	65.5	7.8	1.48	0.75	0.20	0.031	0.027	0.0192	0.174	1.18
	1	F	C	45.5	9.5	1.74	0.84	0.24	0.084	0.037	0.0264	0.226	
	3	F	C	104.5	7.0	0.99	0.45	0.35	0.068	0.030	0.0130	0.192	
	5	F	T	77.5	7.3	1.29	0.59	0.22	0.050	0.026	0.0110	0.190	
	7	F	T	53	9.8	1.70	0.81	0.32	0.055	0.032	0.0224	0.170	

In Table II, column 3, "M" signifies male, "F" female. In column 4 "C" signifies control animal, "T" thyroid-fed rat. The rat numbers given in Table II are those actually used. The rats were taken in the same order in the compilation of Table I.

The lymph-glands selected for comparison were all those macroscopically visible lying in the anterior triangles of the neck along the internal jugular veins, and above the level of the thyroid cartilage. The right anterior tibialis muscle was taken for comparison of muscle tissue.

Consideration of Results

The litter used in experiment 6 was weak and undersized and could not be considered normal; it was not surprising, therefore, that the results in that experiment were not in agreement with those from the remaining five. Experiment 6 will be considered separately.

Total Growth

The results tabulated in Table I show in every case in experiments 1 to 5 a decrease in growth-rate of thyroid-fed animals during the period of thyroid-feeding. In most cases the decrease is marked. This is in complete agreement with our previous observations (2, 3, 4, 6). In the subsequent period the thyroid fed animals had a faster growth-rate in 13 cases out of 17. Of the 4 exceptions one (experiment 1, male) was approximately equal to the control, one (experiment 2, 2nd male) was obviously abnormal, and the remaining 2 (experiment 5, females) were intermediate between the 2 controls.

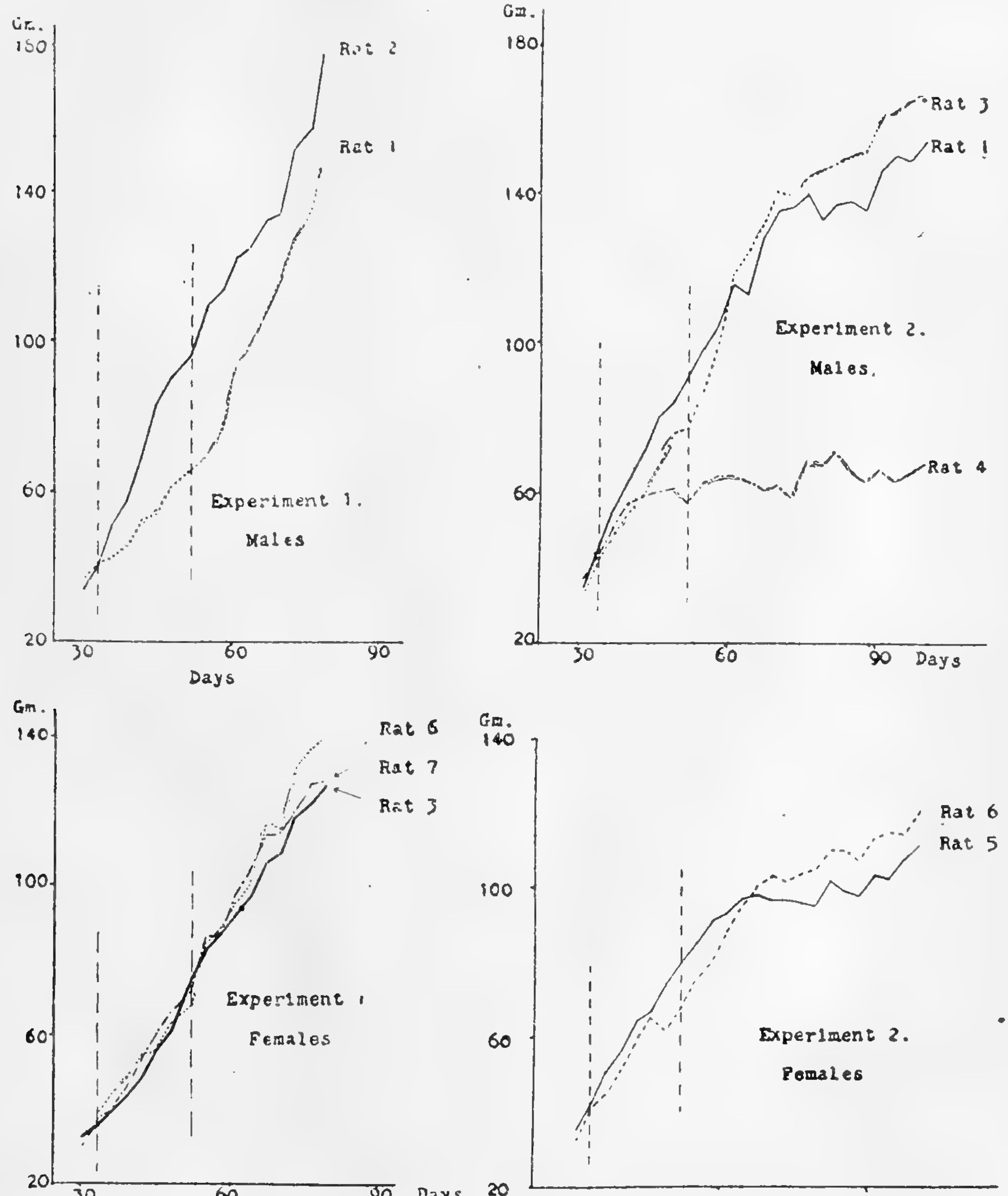

Fig. 1

The total gain in weight was greater in thyroid-fed animals than in their controls in 11 cases out of 17.

The results are shown graphically in figures 1 to 3 (the curves were slightly smoothed by taking the weights for each third day). The curves for males of experiment 4 illustrate very clearly the considerable potential variation in growth of animals even of the same sex and litter. Nevertheless the thyroid-rats during thyroid-feeding had growth-rates one equal to, the other less than that of the slower growing control, while subsequently their acceleration was so great that finally they both exceeded in weight the faster growing control.

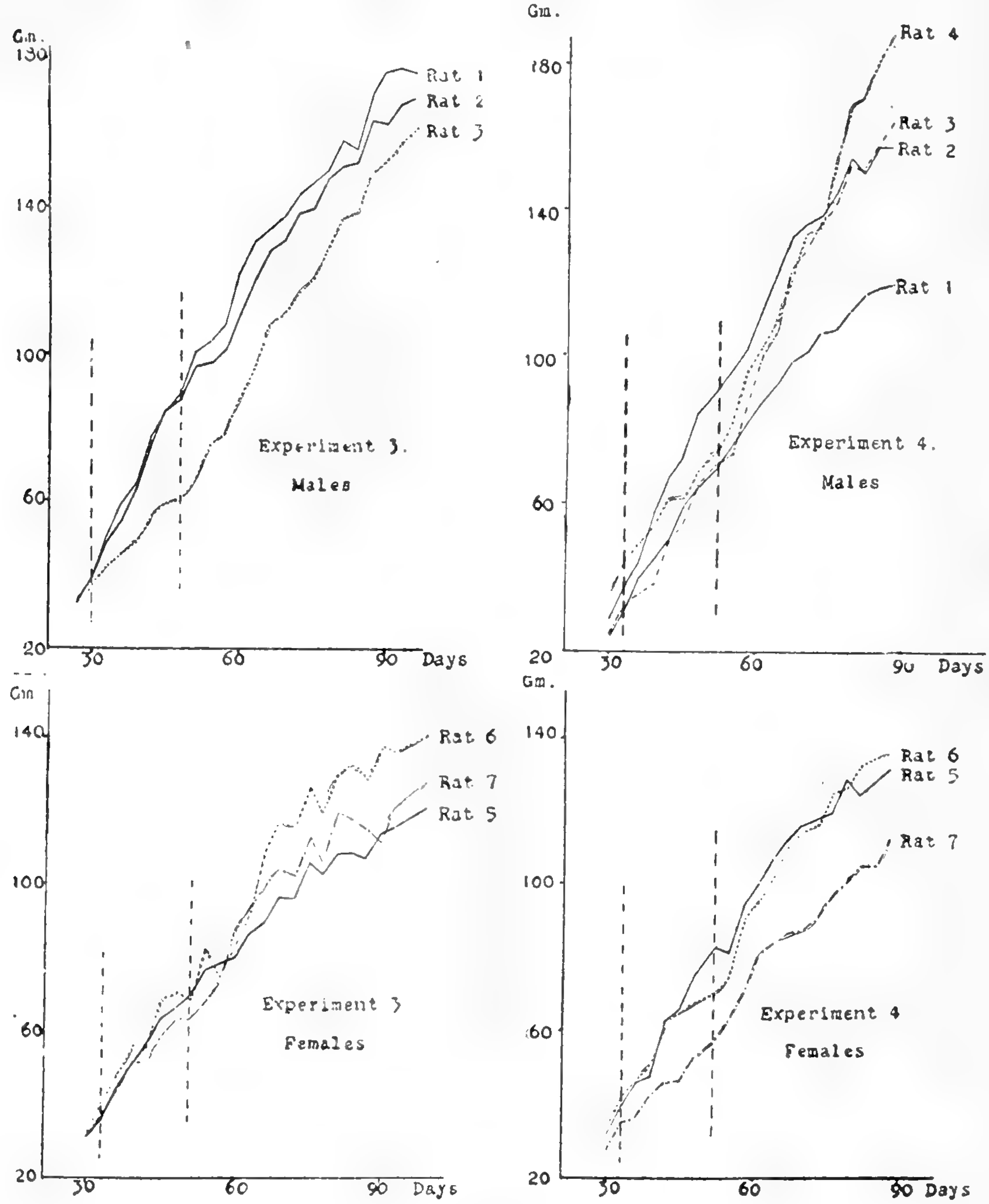

Fig. 2

In spite of the possible variations in controls the results are in such good agreement that the conclusion may be definitely drawn that *during thyroid-feeding of young rats growth-rate is decreased, while after cessation of such feeding growth-rate is accelerated above normal to such an extent that the weights of the treated rats usually exceed those of their controls in from 4 to 5 weeks after cessation of thyroid-feeding.*

The cause of this acceleration is almost certainly associated with the organ-hypertrophy produced by thyroid feeding.

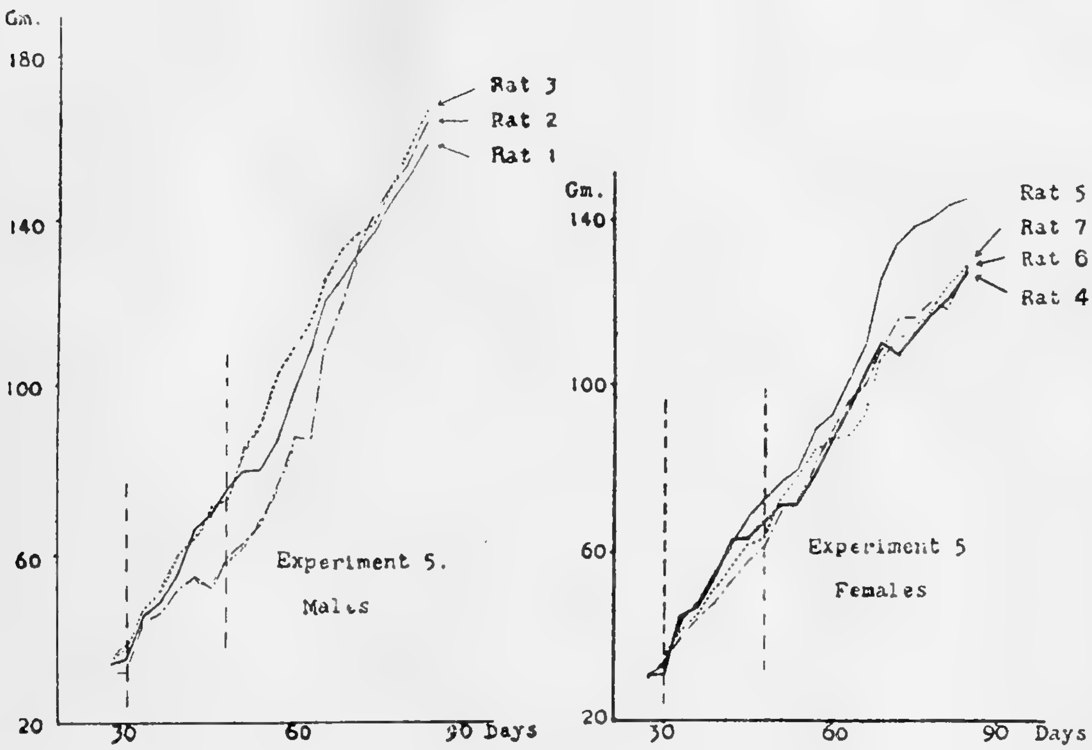

Fig. 3

Hypertrophy of body-organs

In the second of our series of studies of the effects of thyroid-feeding (3) we have summarized (Table XXVI) the effect on the hypertrophy of body-organs under the conditions of the present experiments. With the preparations used, and with rats of approximately the same age, fed thyroid for the same period, hypertrophies are to be expected of the order: liver, 50 to 100 per cent.; kidneys, 30 to 55 per cent.; heart, 20 to 30; spleen, 20 to 40; adrenals, 30 (females) to 60 (males). Other experiments have given, if anything, higher results. Other observers, using larger doses, have obtained distinctly greater hypertrophies (10, 12). We have shown also that muscle tissue is diminished (3, 4, 5, 6) and lymphoid tissue is increased (4, 6). Thyroid tissue is usually diminished in ratio by from 20 to 30 per cent.

Table II, with one or two exceptions, does not show such hypertrophies. Rat 4, experiment 2, and the rats of experiment 6 will be considered later. The differences between experimental and control animals of the same series are usually only a few per cent., and in either direction, and can be considered as within the possible individual variations. An analysis of Table II is given in Table III, expressing the percentage differences (extremes and means) between experimental and control animals. The spleen and lymph glands show greatest variations. Lymphatic tissue seems normally subject to unusually great variations. The adrenals of female rats seem still to be definitely hypertrophied, while thyroid tissue averages distinctly less than normal (but its macroscopic appearance showed that in all cases it was functioning normally). The remaining organs are practically normal.

TABLE III

	Males (7)					Females (9)				
			Extremes		Average %			Extremes		Average %
	Plus	Minus	Plus %	Minus %		Plus	Minus	Plus %	Minus %	
Liver	2	5	9	16	− 5	5	4	19	9	+ 4
Kidneys	5	2	13	18	0	7	2	32	12	+ 6
Heart	4	3	17	6	+ 5	6	3	24	10	+ 7
Spleen	5	2	30	10	+10	6	3	52	22	+ 7
Lymph Glands	4	3	66	23	+10	3	6	19	40	− 9
Adrenals	3	4	43	15	0	9	0	78	0	+15
Thyroid	3	4	16	28	− 8	4	5	19	40	−10
Muscle	6	1	13	2	+ 4	3	6	4	13	− 2
Testes	3	2	4	20	− 4	..	..	..	..	....

Exceptions

Rat 4, experiment 2, and rats 1 (control) and 7 and 9 (thyroid-fed), experiment 6, show markedly enlarged thyroids, and at the same time markedly hypertrophied livers, kidneys, hearts, and adrenals, with (except the last rat) distinctly diminished muscle tissue. The results suggest an actual hyperthyroidism in these rats, and the results for total growth are in agreement. Unfortunately before these results had become apparent the thyroid tissue had been discarded.

Neglecting these obviously abnormal cases it would seem that *in a period of from 4 to 7 weeks after cessation of thyroid-feeding the distinct hypertrophy which is produced in 18 days has almost, if not quite, disappeared.*

We may suppose, therefore, that during thyroid-feeding with such doses as have been employed in these experiments an undue amount of thyroxin is present in the circulating blood. This leads to an abnormal amount of tissue catabolism and at the same time such an immediate oxidation of the circulating food-units that they are in great part broken down before utilization by the tissue cell. This increased tissue activity calls forth a hypertrophy of all the essential organs of the body, heart, liver, kidneys, adrenals, pancreas, etc., with the exception of the thyroid itself, which no longer receives its stimulus to activity (probably fall of thyroxin content of the blood perfusing the thyroid below some definite minimum) and rests. Lymphatic tissue hypertrophies, for some reason as yet unexplained.

When thyroid-feeding ceases the body has become possessed of an engine of higher power than normal. At the same time not only is the thyroxin-stimulus to catabolism removed, but the thyroids, of subnormal size, no longer produce their normal check to growth. Growth-processes proceed at hyper-efficiency. Total growth is accelerated. But the stimulus to hypertrophy of the essential organs is removed, and they gradually become normal.

It is doubtful whether the acceleration so distinctly marked in certain experiments would last. It seems more likely that, with heart and thyroid both approaching normal condition at the end of seven weeks the growth-slope would also again become normal.

Histological Observations

Hashimoto (9) has shown that oral administration of toxic doses of thyroid produces in nearly all cases definite heart lesions ("dense accumulations of large 'histiocytäre' cells derived from the clasmocytes present in the interstitial connective tissue, in small circumscribed areas between muscle fibres, or not infrequently near blood-vessels"). He considers that the interstitial inflammatory proliferation and diffuse parenchymatous degeneration may both be attributed directly to thyroid intoxication. The hearts become functionally inferior. The lesions closely resemble those described by Aschoff and others in the hearts of individuals suffering from rheumatism and correspond with those in goitre hearts. Sub-toxic doses give similar results in the majority of cases, though only small areas are affected.

Most of the other tissues examined showed evidence of increased activity (hyperplasia).

This paper did not come to our attention until the final experiment was in progress. Professor Wm. Boyd, of the Department of Pathology, University of Manitoba, kindly examined histologically the hearts of the six animals which survived to the end of the experiment. It should be remembered that thyroid-feeding had ceased for 18 days. Professor Boyd's report is as follows:

"Areas somewhat resembling those described by Hashimoto, but smaller, were observed in the hearts of rats 1 and 3 (control animals) and 9 (thyroid-fed). I do not regard these bodies as of any pathological importance. They are composed of elongated, epithelial-like cells. The nucleus of these cells is distinct, large, and vesicular, resembling the nuclei of the surrounding muscle fibres.

"I am of the opinion that we are dealing with a small bundle of heart muscle fibres, somewhat compressed, and showing some degeneration of the cytoplasm, which renders the nuclei unduly distinct."

Rats 1 and 9 appear to have been hyperthyroid rats; rats 5 and 7, both thyroid-fed, showed none of these areas. Our results are not in good agreement with those of Hashimoto, but the experiments cannot be regarded as exactly parallel. We hope to obtain fresh evidence on this point in subsequent work.

Tetany

In this paper we have described a number of fresh cases of tetany in young rats which can be directly traced to thyroid-feeding.

So far, in this laboratory, we have records of 193 young rats, of which 65 have been used as controls, 72 have been fed thyroid, 17 thyroxin, 10 parathyroid, 4 large doses of liver, 10 sodium iodide, 9 a vitamin-deficient diet, and 6 this diet plus thyroid. Of these rats there have died, during the feeding experiments 1 control (cause unascertained), 21 during thyroid feeding, 1 on a vitamin-deficient diet plus thyroid, and 1 during thyroxin treatment. Tetany was observed in 6 fatal cases, suspected in 7 others, and observed in a further 4 cases, which recovered. These were all thyroid-fed (or thyroxin-fed) rats. No tetany was observed or suspected in the other fatal cases. Records of 12 adults rat (5 controls, and 7 thyroid-fed) show no tetany. Among the large number of rats reared in the laboratory but not used specifically in any experiment no case of tetany has ever been noticed. Most of the remaining fatal cases due to thyroid-feeding occurred in experiment 8 (2), with half-grown rats fed heavy doses for fairly long periods.

The cases of tetany are summarized in Table IV.

TABLE IV

SUMMARY OF CASES OF TETANY

Animal	Sex	Dose	Initial age	Weight: Initial	Weight: At time of onset	Duration of feeding before onset	Time of onset	Definite or Suspected	Subsequent results
			days	gm.	gm.	days			
(2) Expt. 6, rat 1	M	1:5000	56	50	79	15	?	Definite	Further attacks. Recovery.
" 8, rat 1	F	1:2000	(45)	51	70	8	?	"	Further fatal attack on 10th day
(4) " 4, rat 5	F	1:5000	39	41	59	10	4 p.m.	"	Dead in 15 min.
rat 6	F	1:5000	39	35	60	10	4 p.m.	"	Dead in 40 min.
(5) " 3, rat 3	M	1:5000	39	49	68	10	5 p.m.	"	Dead in 60 min.
Unpublished (Apr. 11th, 1921)									
rat 1	F	1:5000	34	41	46	8	?	Suspected	Found dead
rat 2	F	1:5000	34	37	47	7	?	"	Found dead
rat 3	F	Thyroxin	34	43	43	7	?	"	Found dead
Present series:									
Expt. 1, rat 5	F	1:2000	33	33	51	9	3.45 p.m.	Definite	Dead in 23 min.
" 2, rat 2	M	1:5000	34	49	71	7	?	Suspected	Found dead
" 3, rat 4	M	1:5000	30	38	72	15	"	"	Found dead
" rat 7	F	1:5000	30	37	60	13	4 p.m.	Definite	Passed off in 3 hrs. No further attack
" 6, rat 4	F	1:5000	32	25	35	7	9 p.m.	"	Dead in 70 min.
rat 6	F	1:5000	32	24	30	7	?	Suspected	Found dead
rat 7	F	1:5000	32	26	35	7	5.30 p.m.	Definite	Recovered in 3.5 hr. Attacks on 2 succeeding days. Then normal
rat 9	M	1:5000	32	23	44	16	?	Suspected	Found dead
rat 10	M	1:5000	32	31	44	15	a.m.	Definite	Slight attack; recovery.

In the single case where thyroxin-feeding led to suspected tetany the dosage was at the rate of $1{:}10^5$ of body-weight; a larger dose fed a younger animal than those used in the experiments with thyroxin already recorded (3).

We have already attributed these cases of tetany to the tissue-alkalosis resulting from the prolonged rapid breathing which is an invariable accompaniment. This immediate cause has been described by Collip and Backus (7) and by Grant and Goldman (8), who have produced short attacks of tetany in man by prolonged forced breathing.

Barker and Sprunt (1) have recently described a spontaneous attack of tetany during a paroxysm of hyperpnoea in a psychoneurotic patient (boy, 18) convalescent from epidemic encephalitis. This they attributed to the same disturbance of ratio of cations in the tissue-cells, through the excessive removal of carbon dioxide from the blood.

Although of the young rats fed thyroid at least one out of every seven developed tetany, we cannot yet produce such tetany at will.

The probability of its development seems greater, the younger and smaller the rat when feeding commences. The attacks usually develop after from 7 to 10 days' treatment, and in the majority of definite cases commence from four to five hours after a thyroid dose has been eaten, and before other food has been given.

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XII. *The Progress of Tryptic Digestion of Protein as Studied by the Method of Butyl Alcohol Extraction (Preliminary Communication)*

By ANDREW HUNTER, M.A., F.R.S.C.

(Read May Meeting, 1922)

An approximately 10% solution of sodium caseinate was submitted, in portions of 250 c.c., for varying intervals to the action of a commercial preparation of trypsin. Each portion, at the end of its prescribed period of digestion, was heated to boiling, diluted till the separated tyrosine had dissolved, cooled, and made up to 1,000 c.c. The total and amino nitrogen were then determined in suitable small aliquots. The residue was concentrated, filtered from tyrosine, and extracted with butyl alcohol, according to the method of Dakin,[1] for a total period of 48 hours. In this way the product of digestion was separated into three fractions, corresponding to those obtained by similar treatment of a completely hydrolyzed protein. The total and amino nitrogen of each fraction was determined. The data thus obtained were in each case calculated to the common basis of 100 gms. of nitrogen in the total digest; and in this form are collected in the table. The figures there included as representative of complete hydrolysis are calculated from the best available data concerning the composition of casein,[2] and with the assumption that it contains 2.2% of tryptophane[3].

The experiments were undertaken primarily with the idea of throwing additional light, by a convenient method, upon the rate and order of liberation of the monoamino-monocarboxylic acids, which are extracted by butyl alcohol but precipitated in the extraction flask. It will be seen (columns 8-10) that the fraction containing these acids increases steadily, as was to be expected, with the progress of digestion. The percentage of amino nitrogen in this fraction is, moreover, such as to show that it does essentially consist of monoamino acids in the free state. These can be completely purified, it has been found, by re-solution and re-extraction with butyl alcohol; but this procedure is accompanied by considerable loss. The figures as they stand probably represent, not quite accurately yet fairly closely, the actual rate of liberation of the monoamino-monocarboxylic acids as

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Days of Digestion	Total Digest			Extracted Nitrogen						Residual Nitrogen			Percentage Recovery	
				Butyl-Soluble			Monoamino-acid*							
	Total N	Amino N	Percentage Hydrolysis	Total	Amino	Per cent. Amino	Total	Amino	Per cent. Amino	Total	Amino	Per cent. Amino	Total N	Amino N
1	100	38.0	48	23.7	4.49	18.9	7.0	6.9	98.8	63.6	19.3	30.4	94.3	81.0
2	100	40.9	53	27.1	5.54	20.5	11.7	10.0	85.7	58.5	20.5	34.9	97.7	88.2
5	100	44.5	58	22.0	3.32	15.1	15.2	13.2	86.8	59.7	22.7	37.9	97.1	88.2
10	100	48.9	65	19.0	2.76	14.5	20.8	17.7	84.8	56.4	23.3	41.2	96.4	89.4
∞	100	72.6	100	....	....	....	34.9	33.9	97.1	....	....	....	....	....

*Includes nitrogen of separated tyrosine.

a group. The problem of separating the group at each stage into its individual constituents will be undertaken in the near future.

Perhaps the most interesting, and certainly the least expected, feature revealed by the method is that the digestion product has a considerable proportion of its nitrogen in combinations which are soluble in butyl, and also (as was found) in ethyl alcohol. This butyl-soluble fraction (columns 5-7) appears in the experiment reported to increase at first, and later to diminish, as digestion proceeds; but other experiments have thrown some doubt on the regularity of this particular phenomenon. The exact nature of the alcohol-soluble material is yet in doubt. It is certainly a mixture. Its low content of amino nitrogen shows that it does not consist mainly of free amino-acids, though it always contains a little tryptophane and tyrosine. Most of it is precipitable by phosphotungstic acid. In various ways it has been separated into sub-fractions, but I have not yet succeeded in obtaining from it anything which could be demonstrated to be a single substance. Most of the subfractions have one character in common; when hydrolyzed by acid and subjected to a Van Slyke analysis they yield a high proportion of non-amino nitrogen in the "filtrate from the bases." This non-amino nitrogen stands, moreover, always in some simple relation to the amino nitrogen of the filtrate, such as 1:1 or 1:2. These facts suggest that the material consists largely of polypeptides (or possibly anhydrides), in the composition of which the proline radicle plays a considerable part. The problem presented by this interesting fraction is, of course, being made the subject of further study; for if it should prove possible to isolate by the Dakin procedure, and then to identify, definite alcohol-soluble products of partial hydrolysis, it would probably add a good deal to our knowledge of protein constitution.

It might, perhaps, be suspected that the butyl-soluble material is an artefact, produced by the heating together of many amino-acids in an anhydrous medium. There is indeed one circumstance which rather encourages such a suspicion. The last two columns of the table show that while the total nitrogen is nearly all recovered in the various fractions, there is a decided deficit of the amino nitrogen. *Some* condensation, therefore, of once free amino acids has taken place as a consequence of the butyl alcohol treatment, and it is not impossible that the products of this condensation contribute to the butyl-soluble fraction. Whether this be so or not, the fraction as a whole cannot be produced in such a manner; for (1) if it were, its *total* nitrogen, added to the amino nitrogen of the other two fractions, should equal the original amino nitrogen of the total digest, whereas, as a matter of fact, it is always very much greater, and (2) if the nitrogen of the butyl-soluble and mono-amino fractions be added together, the sum, at every stage except the first day, is greater than the total mono-amino nitrogen (34.9) to be expected even after complete hydrolysis. It would seem, therefore, that in the main at least the butyl-soluble fraction must be a real product of tryptic digestion. I hope to be able in future work to improve the technique of the extraction so that the amino nitrogen of the digest will be completely recovered; if this can be done the uncertainty just discussed will disappear.

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XIII. *A Preliminary Study of the Action of Arginase and of its Possible Use in the Determination of Arginine*

By ANDREW HUNTER, M.A., F.R.S.C., and J. A. MORRELL, B.A.

(Read May Meeting, 1922)

It has been proposed by B. C. P. Jansen[1] that the quantity of arginine in a protein hydrolysate should be estimated by subjecting it to the combined action of the two enzymes arginase and urease, and determining the amount of ammonia (as carbonate) thus produced. Such a method, if its accuracy could be relied upon, would have numerous useful applications; and we have therefore undertaken to study its possibilities.

Before this could be done in any systematic way it was necessary to have on hand some optically pure *d*-arginine. A quantity of the base, prepared from gelatin, was accordingly very carefully purified, converted into the hydrochloride, and as such crystallized twice from 70% alcohol. This product, polarised in approximately 11% concentration and in the presence of 7 moles of free HCl, gave $\left[\alpha\right]_{D}^{20^\circ} = +21.95^\circ$, from which may be calculated for the free base a specific rotatory power of $+26.54^\circ$ These figures are higher than Gulewitsch's,[2] who found $+21.22^\circ$ and $+25.66^\circ$ respectively. We conclude that the rotatory power of *d*-arginine is higher than has been hitherto supposed, and that our preparation was in all probability free from contamination with racemic arginine.

In one of several preliminary experiments 36.77 mgm. of the above hydrochloride, dissolved in 2 c.c. of water was treated with 3 c.c. of a neutral phosphate mixture, 2 c.c. of a neutralized arginase solution, and a few drops of toluene; after the mixture had stood overnight at room temperature the urea produced was determined by the urease method according to the technique of Van Slyke and Cullen. The amount of urea nitrogen found was 4.80 mgm., which is 98.2% of the theoretically possible 4.89. It appears therefore certain that the decomposition of arginine by arginase may, under certain conditions, be practically, if not absolutely, quantitative. In other experiments the yield was much less satisfactory, often as low as 72%. Evidently the conditions leading to a satisfactory result

[1]B. C. P. Jansen: Chem. Weekblad, xiv, p. 125 (1917).
[2]W. Gulewitsch: Zeitschr. f. physiol. Chem., xxvii, p. 178 (1899).

require to be rather carefully defined. We were led, therefore, to study the effect of various factors upon the arginase reaction, and have examined in the first place the influence of hydrogen ion concentration and of temperature.

Hydrogen Ion Concentration. A series of mixtures was made, each of which contained 5 c.c. of an arginine solution (capable of yielding 3 mgm. of urea nitrogen), 5 c.c. of a suitable buffer mixture (series of Clark and Lubs) and 2 c.c. of arginase extract; after one hour at 21°C the action of the arginase was stopped by a jet of live steam, the mixtures were neutralized, and the urea in each determined. The results are shown in Table I.

TABLE I

P_H	Urea Nitrogen Found	Percentage Decomposition	Buffer
4.0	0.18 mgm.	6.0	Potassium hydrogen phthalate —sodium hydroxide
5.0	0.29 "	9.7	"
6.0	0.50 "	16.7	Potassium hydrogen phosphate —sodium hydroxide
6.4	0.62 "	20.7	"
6.6	0.68 "	22.7	"
6.8	0.72 "	24.0	"
7.0	1.18 "	39.3	"
7.2	1.00 "	33.3	"
7.4	0.96 "	32.0	"
7.8	0.73 "	24.3	"
8.0	0.72 "	24.0	"

They show a very sharply defined optimum at $P_H=7.0$. The depressing effect of an excess of hydrogen ions is especially conspicuous. In media of increasing alkalinity the speed of the reaction sinks rather less rapidly; an experiment not included in the table showed that even at $P_H=8.8$ (but in the absence of a buffer) 20% of the arginine was decomposed in one hour.

Temperature. Ten c.c. of arginine solution (capable of yielding 10.86 mgm. of nitrogen as urea) were treated with 4 c.c. of arginase extract, and 5 c.c. of a neutral phosphate buffer solution. The mixture, diluted to 50 c.c., was maintained for one hour in a thermostat at a specified temperature, and the urea determined in the usual way after the activity of the arginase had been destroyed by heat. The results of a series of such experiments appear in Table II.

TABLE II

Temperature	Urea Nitrogen Found	Percentage Decomposition
C.	Mgms.	
10°	1.1	10.1
22°	2.45	22.6
30°	3.2	29.5
38°	4.1	37.7
50°	5.0	46.0
60°	4.2	38.7
70°	0.6	5.5

The data indicate a maximum velocity of reaction at or near 50°C. At 70° the enzyme is practically inactive. If the data be plotted on coördinate axes the graph is practically a straight line between 10° and 50°.

The conditions of the experiment were not such as to permit one to calculate the temperature coefficient of the enzyme reaction. This defect will be remedied in future work.

The influence of other factors (such as substrate and enzyme concentration) upon the kinetics of the reaction is now under investigation.

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XIV. *The Question of the Presence of the Tryptophane Radicle in the Molecule of Hemoglobin*

By ANDREW HUNTER, M.A., F.R.S.C., and HENRY BORSOOK, B.A.

(Read May Meeting, 1922)

It has been stated recently by Fürth and Lieben[1] that the hemoglobin molecule entirely lacks the radicle of tryptophane. Since the other blood proteins are fairly rich in that amino-acid the purity of any specimen of hemoglobin (or of its protein component) might, if Fürth and Lieben's claim be justified, be very conveniently controlled by the outcome of the delicate and characteristic glyoxylic reaction. We have attempted lately to apply this criterion to a number of specimens of globin from horse blood, regarding which we desired to have some assurance that they were free from contamination with the other blood proteins. To our surprise and disappointment every specimen, no matter how thoroughly, to our thinking, it had been purified, gave a positive reaction. We have, therefore, been led to inquire whether tryptophane is not, after all, in spite of Fürth and Lieben's opinion, an actual component of globin.

A solution of horse oxyhemoglobin was obtained by taking a well washed mass of corpuscles, and treating the product with alumina cream for the removal of serum proteins. From a portion of this solution oxyhemoglobin in crystalline form was prepared by the alcohol method. The product was then four times recrystallized.

Globin was prepared from (*a*) the original oxyhemoglobin solution, (*b*) the fourth crystallization, (*c*) the fifth crystallization. All three specimens gave a positive, and indeed quite marked, glyoxylic reaction. It was argued that if this were to be attributed not to the globin itself, but to another protein contaminating the hemoglobin from which it had been prepared, the reaction should at least become feebler with each succeeding attempt at purification. To determine whether or not this occurred we applied the glyoxylic test in such a manner as to yield a rough estimate of the quantity of tryptophane actually present.

Standard solutions of tryptophane were prepared, of concentrations ranging, by steps of 0.01, from 0.01 to 0.1%. Each sample of globin was then dissolved in N/10 HCl in a concentration of 1 per cent. Two c.c. of each standard and of each globin solution were treated

[1]Fürth and Nobel: Biochem. Zeitschr., cix, p. 103 (1920).

with 2 c.c. of glyoxylic acid reagent and 5 c.c. of concentrated sulphuric acid, mixed thoroughly, and allowed to stand for half-an-hour. The colour developed in the globin solutions was then compared with the series of standards. It was found that the globin solutions could not in this way be distinguished the one from the other, and that each gave a depth of colour about midway between that of the 0.02 and that of the 0.03% standard. This corresponds to a tryptophane content for globin of between 2 and 3%.

Since such a method as the above has no claim to accuracy we applied also to our globin samples the quantitative colorimetric method, based upon the Voisenet reaction, which has been proposed by Fürth and Nobel,[2] and by means of which it was that Fürth and Lieben reached their conclusion that globin yields no tryptophane at all. The standard employed was a 0.1% solution of tryptophane. The Voisenet reaction was developed, according to the technique of Fürth and Nobel, simultaneously in 2 c.c. of the standard and in 2 c.c. of a 3% solution of globin. The colours produced were compared in a Duboscq colorimeter. The three globin solutions gave absolutely identical results. With the standard set at 10 mm., each read 12.3 mm., corresponding to a tryptophane content (in the dry globin) of 2.71 per cent. When, as a check upon the instrument, the globin solution was set at 10 mm. and the standard itself adjusted to match, the latter read in every instance 7.7 mm., indicating a tryptophane content for the globin of 2.57 per cent. The average of the two readings was therefore constant at 2.64 per cent.

It is demonstrated, therefore, that repeated recrystallization of oxyhemoglobin does not in the least affect its tryptophane content. This can hardly be explained in any other way than by assuming that tryptophane is an integral part of the hemoglobin molecule. The proportion of tryptophane indicated is moreover quite considerable. It is such as to suggest that the globin molecule contains two molecules of tryptophane; for upon that assumption one may calculate for globin a molecular weight of about 15,500, a figure in close agreement with estimates attained by a great variety of independent methods.

It is not possible at present to explain the discrepancy between our conclusion and that of Fürth and Lieben. The only suggestion we have to offer is that these observers applied the Voisenet test to solutions of globin that were too dilute. They do not, for this particular protein, give any data upon which the concentration of their

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[2]Fürth and Lieben: BioMhem. Zeitschr., cix, p. 124 (1920).

solutions could be estimated. The Voisenet reaction is a less delicate test for tryptophane than the glyoxylic test; it fails, as we have ascertained by experiment, with a 0.001% solution, while the latter is still faintly positive at 0.0001%. If Fürth and Lieben had applied the glyoxylic test to their globin solutions they might have come to a different conclusion.

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XV. *The Bar of Sanio and Primordial Pit in the Gymnosperms*

By H. B. SIFTON, M.A.

(Read May Meeting, 1922)

Sanio's well-known investigation of the development of the secondary tissues in the Scotch Pine contains the first attempt at critical study of the structures to be considered in this paper. Using material which had been freed of protoplasm by heating with acetic acid, he noted that the cambium cells and the very slightly enlarged cells adjacent to them on the side of the wood are provided with smooth walls of even thickness. Before these wood elements have reached their full size, however, rounded, thin places are observed to form on their walls, and these thin spots enlarge with the growth of the cells. Sanio notes that while horizontally these primordial pits shade off gradually into the thicker portion of the cell wall, the edges above and below are sharply delimited, appearing when mature with "döppelten Umrissen." Since the time of Sanio's publication improved methods of staining have shown that the "double rims" which he observed were merely the edges of a newly developed structure, a thickening in the primary wall of the cell forming a curved ridge above or below the primordial pit. To these ridges the name "Rims of Sanio" has been applied. Where the pits approximate the adjacent rims fuse, taking the form of "Querleisten," the so-called "Bars of Sanio." As seen in tangential section, Sanio refers to these bars as "knotenförmige Verdickungen der Membran zweier Nachbarzellen." On the thinned spaces, or primordial pits, the bordered pits of the secondary wall are formed.

Until the year 1910 very little attention was paid to bars of Sanio, but in that year a paper on their distribution by Miss Gerry (2) aroused a great deal of interest among those engaged in the study of conifers, especially those interested in fossil forms. A paragraph from her conclusions will illustrate the value attached by her to the rims of Sanio:

> The distribution of the bars of Sanio above described establishes a constant and useful diagnostic character in the determination of fossil woods. In woods with Abietineous affinities we always find bars of Sanio even though at the same time we may find more or less Araucarian-like pitting. But in the Araucarineae we never find bars, although in fossil forms such as the Araucariopityoideae and the Brachyphylloideae, we find Abietineous as well as Araucarian pitting.

Miss Holden, whose scientific career was unfortunately cut short through the war, made frequent use of Miss Gerry's generalization in her work in fossil botany (4), (5), (6) and (7), considering the presence of bars of Sanio "by far the most reliable criterion for disgnosing coniferous woods."

In 1912 Jeffrey (8) recorded the discovery of bars of Sanio in the secondary wood of the cone axis of four species of Araucaria. He notes in his description that each bar does not extend across the tracheid but only across the width of a single pit. The forking where the two rims separate at the ends is also emphasized as one of the indications that the structures are true bars of Sanio. The presence of such bars in a conservative region, like the cone axis, of a form where, as recorded in Miss Gerry's work, it is normally absent, was held by Jeffrey to indicate ancestry from forms which normally had bars of Sanio in their tracheids, and contributed largely to his general conclusions that "the Araucarineae cannot have been derived from the Cordaitales" and "any hypothesis as to the origin of the Coniferales in general must start with the Abietineae as the most primitive tribe." In further support of this theory he states his failure to find bars of Sanio in regions near the primary wood of Cycas, Zamia, Ginkgo, or even Pinus. All of these forms, except the last, are by general consent placed among the most primitive living gymnosperms, where Jeffrey's theory also places Pinus, although the position of the latter is disputed by other botanists.

Thomson (12) also noted the presence of a bar of Sanio in Araucarian wood and considers that it is present in rudimentary form not only in the transitional region of such parts as the cone axis, but in the normal stem wood of all the Araucarineae. He noted that the type of bar in conservative regions of the Abietineae resembles the Araucarian bar, while that in more specialized parts differs from it considerably. The suggestion was made that this difference may be connected with an increase in the size of the pitting.

Groom and Rushton (3) made a careful chemical study of the structures in *Pinus Merkusii*, concluding that they are at least partly pectic, and not composed of cellulose as assumed by other writers. After giving an account of their microchemical investigations they say:

> Combining the above given facts with Sanio's account of the development of pits in the primary pit-areas the following would, therefore, appear to be the truth. When young the actual marginal portion of the primary pit-area does not thicken by deposits of lignified wall so soon as it does elsewhere (except on the pit-closing membrane) but thickens by successive deposits of pectic substance until a stage is

reached when lignified wall-substance is deposited even over the now thickened rims of the primary pit-areas. Sanio's rims represent a system of rod-like or band-like pectic thickenings of the middle lamella running transversely in the radial walls and linked here and there by slightly curved, longitudinal, band-like, similar thickenings (representing the lateral margins of primary pit-areas).

Bailey (1) in 1919 published the results of researches undertaken with a view to ascertaining the origin of the rims. He suggests the identity of the bars of Sanio seen in Araucaria with the normal bands of primary wall situated between the scalariform primordial pits in ferns, and believes that rims and bars in other genera of the conifers and in other groups as well are of the same character. His hypothesis is based on the premise that when a scalariform gives place to a row of shorter bordered pits the primordial scalariform is not similarly cut up. He observes further that in some cases "the elongated bordered pits become replaced by vertical rows of smaller pits which are staggered so that the pits in one row alternate with those of the next series. These pits are usually superimposed over nearly the whole surface of the primary pit areas, and the thicker portions of the middle lamella tend to anastomose or form a reticulum." This, he suggests, accounts for a normal lack of typical bars of Sanio in forms where alternate pitting is strongly developed and makes it difficult to explain how forms with these structures well developed can be descended from ancestors with alternate pitting. In a number of Angiosperms he finds evidence to corroborate his theory, the pits being arranged in long, horizontal rows with bars between, so that the structure of the primary wall is suggestive of that found in lower forms with scalariform bordered pits.

In 1915 the writer (10) discovered bars similar to those previously noted in Araucaria, in the petiole of Cycas, and later (11) recorded such structures in the secondary wood of *Dioon spinulosum*. Their presence in forms, which are recognized as among the most primitive of living seed plants and which cannot be held to have descended from Abietineae, suggested the correctness of Thomson's idea that this type might be the primitive one from which the Abietineous form originated. It was, therefore, considered worth while to investigate the types of rims or bars throughout the Gymnosperms in the light of this additional knowledge of their occurrence. For convenience of reference certain of the photographs formerly published have been repeated in this paper.

As indicated by the title, the primordial pit of Sanio will be given a considerable amount of attention since rims of Sanio have not been found apart from these thin places in the primary wall.

They are not, however, as Sanio apparently supposed, merely the sloping edges of the hollow.

Fig. 1, Plate I, a portion of a tracheid from the petiole of *Zamia integrifolia*, illustrates the type of broad-bordered scalariform from which the bordered pits of more specialized woods are, from the writer's standpoint, considered to have developed. It will be seen that while in some parts of the tracheid the scalariforms are horizontal, in other parts they are less regular, passing in a diagonal direction across the tracheid. Filling in the space between the diagonal and the horizontally placed scalariforms are the ends of others. The long, slit-like pores reach from end to end of the pits, and the comparatively wide borders can be plainly seen. Between adjacent pits dark lines are shown in the photograph. These appear dark blue in the section, being portions of the primary wall, stained with Haidenhain's haematoxylin. The portion covered by the borders is lighter in colour because the primary wall is thinner in this region. In other words, each scalariform exactly covers a long, narrow primordial pit of the same nature as those described by Sanio in Pinus. The strips of primary wall between the pits, where it has retained its normal thickness, are, according to Bailey's view, bars of Sanio.

Fig. 2, Plate I, is a tracheid from the petiole of *Cycas revoluta*. It shows in face view scalariforms which have been cut up to form shorter bordered pits. Near the centre of the figure is one scalariform which persists as a single pit reaching from side to side of the cell, but constrictions can be seen in the border, indicating what might be described as an abortive attempt at division into three. On the rest of the tracheid complete divisions are observed, producing bordered pits which are round, or more or less elongated. It is plainly to be seen that the dark lines extend vertically as well as horizontally between these pits. In other words, each bordered pit has its own separate primordial pit surrounded on all sides by primary wall of normal thickness. This is true though the pits are so arranged that there can be no doubt of the formation of a row of them on what was ancestrally a single scalariform. Even the single scalariform which is left has the thicker primary wall extending into the constrictions on its sides. Sometimes in Cycads one sees a tracheid where the scalariform primordial pit is retained and has a row of bordered pits on it, and this was quite possibly a typical condition in the ancestral forms where multiseriate pitting first originated. The fact that such a habit has largely been lost in forms as low as our living Cycads and that the loss is not dependent on alternation of pitting, is cause for doubt as to Bailey's theory on the origin of the bar of Sanio.

Fig. 3, Plate I, also from a Cycas petiole, shows tracheids representing a stage of development beyond that shown in Fig. 2. It will be noticed that the bordered pits are not crowded over the entire surface of the tracheids as in the former figure. In the upper part of the tracheid at the right several bordered pits are plainly missing. The primordial pits remain and are shown as lighter areas surrounded on all sides by dark lines where the middle lamella has not become thinned. Primordial pits on which bordered pits are not superimposed appear darker in the photograph than the others, owing to the fact that the total thickness of the secondary wall covers them. Similar areas, though with the primordial pits less sharply outlined, are present in other parts of the section. Another important development is also present. Above and below certain of the pits the middle lamella is thicker than at their sides, a fact indicated by the deeper staining. This is true not only where opposite pitting is in evidence, but in cases where the pits are alternate and where, if Bailey's theory is correct, the thick part should form a reticulum enmeshing the pits. Several points suggest very strongly that this is an extra thickening of the membrane at the edge of the primordial pit and not merely the normal, unthinned middle lamella. Thus in the left hand tracheid of the figure there are to be seen thickenings in the form of arcs closely applied to the edges of the bordered pits. I have not applied microchemical tests to ascertain whether these arcs are of pure cellulose or of a pectic nature as Groom and Rushton found them to be in *Pinus Merkusii*, but their form and position leave no room for doubt that they are true rims of Sanio. Where the pits are closely approximated the two adjacent rims fuse forming Sanio's "Querleisten." These structures, as in a former paper (10), will be referred to as "bars" of Sanio. In one or two cases, where the pits are not crowded, the rims are separate from each other, e.g., between the second and third pits above the pair of opposite ones.

Fig. 4, Plate I, shows the same structures in the cone axis of *Araucaria Bidwilli*, where they were discovered independently by Jeffrey and by Thomson. In two tracheids of this figure the pitting is opposite, and if Bailey's theory of the bar were correct the structures should extend in unbroken lines from side to side of the tracheid. This, however, is not the case. Each pit has a rim clinging to its edge with the result that small diamond-shaped areas of a lighter colour can be seen between the pits.

Fig. 5, Plate I, illustrates bars of Sanio as seen in a radial section of the stem of *Dioon spinulosum*. The pitting is more or less scattered owing to the elimination of certain of the bordered pits. On the upper part of the right-hand tracheid are seen bars which, unlike those in Figs. 3 and 4, pass beyond the area covered by the bordered pit with which they are in contact. Their mode of origin is indicated by the bar just above the three grouped pits at the bottom of the figure on the same tracheid. The constriction in this bar shows it to be formed by an imperfect fusion end to end between two short bars, one connected with the bordered pit and the other with an adjacent primoridal pit on which no secondary pit has formed, and which shows a tendency to disappear. On the tracheid to the left are shown several bars, some of which strike the sides of bordered pits, indicating that the primoridal pitting is alternate. These are interesting from their pronounced thickness as compared with that of the normal primary wall at the sides of the bordered pits, thus bringing out their nature as superimposed structures.

In many cases bars of exactly the appearance of those noted by Thomson in the stem of Araucaria are seen in Dioon. Such structures are plainly indicated in Fig. 6, Pl. II, separating the six closely approximated pits in the upper half of the right-hand tracheid. Above this group, where the pitting is more scattered, separate rims are in evidence, closely approximated to the bordered pits. The structures are plentiful in the remaining tracheids of the figure, of which the one to the left is especially to be noted, the upper portion showing bars of Sanio in a region from which secondary pits have been entirely eliminated.

The method of elimination of bordered pits to produce the "scattered" condition is illustrated in the central portion of Fig. 6, particularly in the second tracheid from the left. In regions of elimination certain of the pits have become smaller than normal. In carefully stained sections the primordial pits of normal size are to be seen with these small bordered pits in the centre, but their outline is so delicate as contrasted with that of the bordered pit that it is difficult to reproduce in a photograph. The condition has been caught by the camera in one case near the centre of the tracheid under consideration. This is the most primitive living plant in which bordered pits which do not cover the whole area of the corresponding primordial pit have been recorded. Elimination pitting also occurs in the Cordaitales and the Araucarineae, and is important in that it makes way for the larger pits found in the wood of more specialized forms.

For convenience of presentation the remaining groups are considered in the following order: Cupressineae, Taxodineae, Abietineae, Taxaceae, Gnetaceae and Ginkgoaceae. Needless to say, the arrangement is not to be taken as an indication of supposed phylogenetic relationship. Ginkgo is reserved to the last because it is regarded as a special form due to certain features of arrested development.

Fig. 7, Plate II, a radial section of secondary wood from the root of *Chamaecyparis obtusa* (*Retinospora lycopodioides*) illustrates an advanced condition approaching the most specialized in the higher Gymnosperms. With the elimination of large numbers of the pits, which covered the whole radial surface of the tracheids of the lower Gymnosperms, comes the possibility of enlargement for those that are left. In the form under consideration this enlargement has taken place to a very noticeable extent. The primordial pits, outlined by their rims of Sanio, have here increased to a greater area than have the bordered pits, and the rims of Sanio are thus no longer in contact with the latter. The point with regard to these, however, is that while the bordered pits of the secondary wall have been reduced to a uniseriate condition the same is not true of the primordial pits. In each case the bordered pit appears superficially to be inserted on a simple primordial pit reaching from side to side of the tracheid, but a consideration of the rims of Sanio leads to a different conclusion. At the centre of the second tracheid from the left, for example, the bars are plainly in horizontal pairs with a clear space separating the ends. The primordial pits have enlarged, overlapped and fused horizontally, but the end to end fusion of their rims of Sanio is not yet completed, and the gaps indicate the compound origin of the large primordial pit. The forking ends of the short bars show that each is a true bar of Sanio, composed of two vertically fusing rims. In other parts of the section the fusion of bars is complete. In the second bar from the top of the third tracheid from the left the bars are completely united, while the compound nature of the primordial pit is indicated by the imperfectly fused bars below it. In the stem of Chamaecyparis complete fusions of the bars are the rule.

It is generally admitted that the ancestral pitting for this and other conifers is multiseriate, and each of the shorter bars discussed above would thus be formed of two or more which have overlapped and fused. This overlapping accounts for the thickness of the bars in this and higher forms, where it is more pronounced than in forms like the Cycads and Araucarians.

Chamaecyparis is not the only genus of the Cupressineae which indicates the mode of formation of the complex bar of Sanio of the higher forms. In the root of Thuja, in regions of biseriate pitting, it is often in evidence. Fig. 8, Plate II, illustrates a fairly common condition in the root of *Thuja occidentalis*. Near the centre of the second tracheid from the left are shown bars incompletely fused, though the ends are not forked as in the very suggestive example illustrated in Fig. 7. The stem of Thuja shows a similar condition in regions, such as the ends of tracheids, where biseriate pitting is in evidence. The typical condition in the stem, however, is illustrated in Fig. 9, Plate II, where the pitting on the rather irregular tracheids is uniseriate and the rims and bars are so perfectly fused together as to give no hint of their compound nature. At the right of the figure is shown a little of the summer wood with its narrow lumina and small pits. The rims of Sanio do not come out clearly in summer wood, owing probably to the heavy lignification, but they may be seen between the second and third pits from the top, to be of the same essential nature as those of the spring wood.

A study of several other members of the Cupressineae revealed no great variation in structure from the points already mentioned. In the root of *Thuja Standishii* indications of incomplete fusion of the rims were found, while in the stem the specialization is apparently complete. Material of *Cupressus Benthami* seedling, and various regions of *Thuja plicata*, *Thuja orientalis*, and five species of Juniperus was available and in all of these the development of the compound bar is, as a rule, complete. Doubtless relics of the ancestral characters are present in the most conservative regions of some or all of these forms, but they are less plentiful than in those which have been described more in detail.

There is a fairly general tendency for the bars to appear less strongly marked in stem than in root wood, either through their partial lignification or for some unknown cause. They are, however, sufficiently definite to indicate clearly their homology with those illustrated in the stem of Thuja (Fig. 9). Even where, as in some species of Juniperus (e.g., *J. communis*, *J. davurica* and *J. occidentalis* stems) they have become shortened, it is quite apparent, even without the evidence furnished by the roots, that they border enlarged primordial pits such as have been described.

Passing to the Taxodineae, evidence of the development from the Cycadean-Aruacarian type of primordial pit and rim of Sanio to the more specialized form is again found. Fig. 10, Plate III, is a radial section of the root of *Taxodium distichum*. The pitting here is less scattered but there is evidence of a considerable amount of elimination. In the two middle tracheids there has been a reduction at least from the triseriate to the biseriate condition and the bordered pits have not enlarged sufficiently to fill the space left by the central row which was eliminated. There has not been room for the primordial pits to enlarge to a great extent vertically but they have done so in a horizontal direction, and fused to form long, narrow pits bordered above and below by straight bars of Sanio passing from side to side of the tracheid. That these bars are compound structures is shown in some cases by constrictions which divide them into three parts corresponding to the ancestrally triseriate primordial pitting. This condition is marked in the seventh bar from the bottom of the second tracheid from the right and in the sixth from the bottom of the tracheid to the left of this. It is to be seen also in others. In this triseriate condition it is remarkable that divisions between the bars, crowded end to end as they are, should be evident even to the degree shown. The divisions are delicate and difficult to photograph, but can be clearly seen in the section.

As shown in the photograph, uniseriate bordered pits are also found in the root of Taxodium, though to a less extent than in the stem, which is illustrated in Fig. 14. The bordered pits are larger in proportion to the width of the tracheid, but not large enough to fill the compound primordial pits, which are bounded above and below by well marked rims whose components have become perfectly fused.

In other members of the Taxodineae which were available for study the pits even in the roots are more reduced in number, there being a tendency toward the uniseriate condition. In these the bordered pits are inserted typically in broad primordial pits which they do not completely cover, but whose rims have lost any indication of their compound nature. The ancestral condition is indicated in very conservative regions by the presence of bordered pits completely covering the primordial pits and with rims of Sanio closely attached to their borders. This condition will be again referred to when the Abietineae are considered. It has been observed in the seedling root of *Cunninghamia sinensis*, and in the root of *Sciadopitys verticillata* near the primary wood.

Fig. 11, Plate III, is a radial section of the stem of *Abies amabilis* and illustrates typical Abietinean pitting. The bordered pits are large as compared to those of the Cycads and Araucarians, and are placed in primordial pits which are still larger, resembling in every respect those whose development has been traced in the Cupressineae and the Taxodineae. The rims of Sanio do not normally touch the borders except where the pitting is somewhat crowded and even here they pass beyond the individual bordered pit horizontally. In other words, the primordial pits to which the rims attach themselves have increased greatly in height wherever there is room, and even where crowded they are broad, usually reaching across the face of the tracheid.

That these large primordial pits have originated in the same way as those of the families considered above is proved by a consideration of conservative regions. Fig. 12, Plate II, shows a tracheid from the root of *Pinus strobus* close to the primary wood. The pits are uniseriate, scattered and enlarged, but well marked rims of Sanio are to be seen clinging closely to their borders. In this primitive region the ancestral condition where the size of the primordial pit has not increased beyond that of the bordered pit is retained. Jeffrey (8) apparently overlooked the rims of Sanio in this region, for he states that in Pinus "bars of Sanio make their appearance late, and not in proximity to the primary wood," a statement which might be considered correct had Jeffrey made the distinction between bars and rims of Sanio. This, however, he did not do.

A recapitulation of the development of the large, compound primordial pit from the primitive type shown in this figure is exhibited as one passes from the primary wood outward in the roots of various Abietineae. Indications of the fusing of rims end to end occur in a figure of *Larix americana* root by Thomson (12), and have been observed by the writer in the root of *Pinus Lambertiana* and *Pinus strobus.* As one passes out from the centre of the root the primordial pits become larger until the maximum size is reached and the pits and rims have fused to produce a condition such as that illustrated in Fig. 11.

The primitive rim of Sanio is to be seen in other parts of the Abietineae than the roots. In Fig. 13, Plate III, it is present in a radial section of the secondary wood of the cone of *Pinus resinosa* close to the primary xylem. The photograph is poor owing to the irregularity of the tracheids in the region, but rims of Sanio are in evidence in close contact with several of the bordered pits.

In the adult wood throughout the Abietineae, minor variations in primordial pitting are present, though the general type illustrated in Fig. 11 is preserved. In the Cedrus stem the rims were sometimes closely applied to the pits. This was observed in wounded material, and the wounds may account for the primitive character. Near the pith, in this form, the same tendency was observed. The nine species of Pinus investigated all showed the typical specialized form of rim though with variations in staining properties.

In the Taxaceae the rims of Sanio show evidence of the close relationship of the family to the Pinaceae, for it is evident that the same process of evolution has been followed. In young Dacrydium seedlings the rims are closely approximated to the bordered pits in true Araucarian fashion while in the adult stem they have drawn away and are often much elongated. The same adult structure is found in Podocarpus, Saxagothaea, Phyllocladus, Torreya and Taxus. A further tendency in the evolution of the primordial pit is illustrated in the family, however, and it is important because it apparently leads up to the Gnetalian and lower Dicotyledonous types. The vertical height of the enlarged primordial pit lessens so that while it still reaches from side to side of the radial wall of the tracheid, its edges approach those of the bordered pit above and below. Fig. 15, Plate IV, is a radial section of the root of *Torreya nucifera* where this development has not yet been consummated. Tertiary thickenings, characteristic of the Taxineae, are present, but the primordial pits and rims of Sanio are of the Abietinean type. Fig. 19, Plate IV, is a radial section of the stem of *Taxus cuspidata*, where the tertiary thickenings are still more in evidence. The rims and bars of Sanio are faint but may be made out quite clearly in several of the tracheids. In the Pinaceae such primordial pitting has been noted in regions where the elimination of bordered pits has not gone far enough to permit of vertical expansion, but here it is seen even where the pits are separated, for example, near the centre of the third tracheid from the left, and the condition in primitive Taxaceae, as well as in the more primitive parts of the Taxineae themselves (e.g., the root of Torreya, Fig. 15), suggests that it is a further modification of the specialized compound primordial pit.

Fig. 17, Plate IV, is a radial section of the stem of *Gnetum scandens* showing a part of the wall of one of the enormous vessels characteristic of this vine-like form. Between the rows of pits are particularly heavy bars of Sanio outlining long, primordial pits which suggest those of the lower Angiosperms. Their vertical height is very small when compared with the width of a complete vessel, so that, as in the Dicotyledonous form, they at once suggest the primordial scalariforms of Fig. 1, Plate I. A consideration of the wood of other members of the Gentales, and of conservative regions of *Gnetum scandens* itself suggests a different origin.

Fig. 18, Plate IV, is a radial section of the stem of *Ephedra gerardiana*, where the vessels are not so large. Rims of Sanio are not strongly marked but are quite evident, especially in the element to the right. They and the primordial pits enclosed are similar to those of Taxus, and there is nothing to suggest a different origin.

Were no further evidence at hand it could scarcely be considered probable that the rims of Sanio in Gnetum are simply relics of the ancestral scalariform while those of the closely related Ephedra are the outcome of the series of developments outlined in this paper. Fig. 16, Plate IV, however, shows the Taxus type of rim in *Gnetum scandens* itself, in the primary wood. At the left of the figure is a scalariform tracheid, indicating proximity to the protoxylem. The right-hand tracheid belongs to the metaxylem and in it the structures referred to come out clearly between the bordered pits. In general, the phylogenetic development of the metaxylem in a group of plants follows along the same lines as that of the secondary wood, but is less advanced, and in other families of the Gymnosperms where a rim of Sanio has been observed in this region, it is of the Araucarian type. The presence in the primary wood of Gnetum of bars such as those illustrated is, therefore, further ground for assuming that the long, well marked bars on the vessels of the secondary wood are a culmination of the series of developments outlined.

A study of various regions in the Dicotyldeons with reference to the bar of Sanio is beyond the scope of this paper, but from the appearance of the structures and the description of them in anatomical literature there is no reason for assuming their origin to be different from that of those found in the Gnetales.

The Ginkgoaceae, of which *Ginkgo biloba* is the only living species, will now be considered. In this form the pitting is generally described as opposite, with bars of Sanio passing from side to side of the tracheid. It is found on careful examination, however, that the elimination of pitting has not gone so far in this as in higher forms, and so the bordered pits and the primordial ones on which they are formed have enlarged to a less extent than those of such forms as the Abietineae. This can easily be seen by comparing the pitting of Ginkgo as shown in Plate IV with that of *Abies amabalis*, which is shown at less than half the magnification in Fig. 11, Plate III. The compound primordial pit and bar of Sanio is thus arrested in this form, in the midst of its development and, as would naturally be expected, incomplete stages are very plentiful.

Fig. 20, Plate V, is from a young stem of Ginkgo, near the pith, and typical Araucarian pitting is shown. In the left hand tracheid the pits are alternate and flattened to hexagonals by mutual contact—a condition typical of the stem in the Araucarineae. This flattening of the borders is apparently not a primitive condition for the forms in which it is plentiful for it is not characteristic of the most primitive regions of such forms as the Araucarians. In such places the pits are rounded, and separated by appreciable bands of the cell wall (see Fig. 4, Plate I). The crowding is due, apparently, to the general tendency toward enlargement of pitting even in forms where elimination has taken place to a slight extent or not at all. In the right hand tracheid of Fig. 20 the pits are more scattered, and retain their rounded contours. The only bars or rims of Sanio in the figure are of the short, narrow type found in the Araucarian stem.

Fig. 21, Plate V, is from the short shoot of Ginkgo. Medullary ray cells at the upper right indicate that in the right half of the figure we are dealing with secondary wood, but the pitting at the left is that of the metaxylem. The three right hand tracheids have alternate pitting. The pits are not flattened by mutual contact, and above and below them are bars of Sanio of the type seen in the cone axis of Araucaria (Fig. 4, Plate I). The forking at the ends is plain, especially in the third tracheid from the right.

Fig. 22, Plate V, shows the ends of two stem tracheids, and is included because it illustrates a stage often found in Ginkgo. The two pits at the bottom of the right hand tracheid have what appears on casual view to be a straight bar of Sanio between them, but close examination shows two separate rims with ends overlapping but not fused, each rim being connected with its own pit. The rest of the figure has the compound bars rather well fused.

Fig. 23, Plate V, which is from the root, presents a special form of rim resembling that of higher forms more closely than the usual Ginkgo type. There has here been a considerable enlargement of the primordial pits and the rims are curved, and more heavily marked than usual. In parts where the pitting is somewhat crowded, however, their compound origin is still in evidence. See, for example, the thinning out at the centre of the second and third bars from the bottom, and the diamond-shaped, clear area in that fifth from the bottom. Fig. 24 shows bars similarly thinned out at the centre alalthough here the pitting is uniseriate and the thinned place comes opposite the bordered pit. Thus it cannot be said that the gaps are due to a tendency of scalariform bars to break up and adhere to the bordered pits. In the light of the evidence from primitive regions and primitive forms, their presence is easily explained as a relic of the condition in which short bars, each composed of the rims of two vertically adjacent, small primordial pits, were arranged in a series, end to end, across the tracheid.

The three remaining figures illustrate common types of bar in Ginkgo. Fig. 25 is from the same region as Fig. 20, and here the short bars have fused end to end, though the enlargement of primordial pits in comparison to the size* of the tracheid is small. Under these conditions the bars naturally present a condition closely resembling that found in the stem of *Dioon spinulosum*. The condition shown in Fig. 26 is very common in adult wood—the pits uniseriate and rather close to each other but with clear-cut bars between. In Fig. 27 the secondary pitting has been almost completely eliminated, but the bars are left.

It is thus quite apparent that, owing to the partially arrested development of the primary wall at a stage midway between the Cycadean-Araucarian structure and that found in higher forms, the species is peculiarly rich in evidence bearing on the development of the compound rim and bar of Sanio. A complete series of developmental stages is easily obtained from the one plant. The Araucarian bar is seen in very conservative regions from which Jeffrey believed that all bars were absent, and stages from this to the advanced Abietinean type are scattered freely through the secondary wood of root and stem. Such a condition is in complete agreement with the line of development outlined in the present article.

Summary

1. A study of primitive forms of pitting indicates that soon after short, bordered pits formed on the ancestral scalariforms, the scalariform primordial pits also gave way to rows of shorter ones.

2. Rims of Sanio are probably not relics of the old, primary scalariforms, but new structures resulting from an extra thickening of the primary wall at the edges of primordial pits.

3. The bars or "Querleisten" of Sanio are formed by vertical fusion between the rims of closely approximated primordial pits.

4. Numbers of the bordered pits which covered the radial walls of tracheids decreased in size and were finally eliminated, after which the remaining pits, both primary and secondary, enlarged.

5. The growth of the secondary bordered pit failed to keep pace with that of the primordial pit, which gave rise to rims of Sanio at some distance from the edges of the borders.

6. In all the higher Gymosperms the enlargement of primordial pits caused an overlapping and fusion of horizontal rows into single broad ones reaching across the tracheid.

*It should be remembered that, as noted by Sanio, the primordial pit increases in size with the growth of the tracheid. This being so the *absolute* size of the primordial pits is not of great phylogenetic interest, through their enlargement *as compared with the size of the tracheid on which they are placed*, is significant.

7. The compound nature of these broad primordial pits is indicated in conservative regions of several forms by the incomplete horizontal fusion of the bars and rims of Sanio.

8. In specialized woods the rims or bars connected with these fused primordial pits have also completely fused, and probably overlapped to form a heavier bar than in the lower forms.

9. There was a final tendency for the compound primordial pits to become narrowed vertically while retaining their horizontal breadth, which probably led to the condition in the lower Dicotyledons.

10. In Ginkgo, the elimination of pitting and the subsequent enlargement of primordial pits did not proceed so far as in higher forms. As a result this form is particularly rich in indications of the mode of origin of the compound rims and bars of Sanio.

To Professor R. B. Thomson, under whose supervision this work was carried out, I am indebted for advice and encouragement, and for a copious supply of material from his collection.

Botanical Laboratories,
University of Toronto,
May 31st, 1922.

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DESCRIPTION OF PLATES

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Fig. 2.—*Cycas revoluta*, petiole; transitional pitting on primary wood. ×340.

Fig. 3.—*Cycas revoluta*, petiole; tangential of primary wood showing bars and rims of Sanio. ×340.

Fig. 4.—*Araucaria Bidwilli*, radial of ovulate cone; secondary wood showing bars of Sanio. ×340.

Fig. 5.—*Dioon spinulosum*, radial of stem; secondary wood showing bars of Sanio. ×340.

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Fig. 7.—*Chamaecyparis obtusa* (*Retinospora lycopodioides*), radial of root; showing enlarged pitting, both primordial and secondary, and bars of Sanio whose horizontal fusion is incomplete. ×340.

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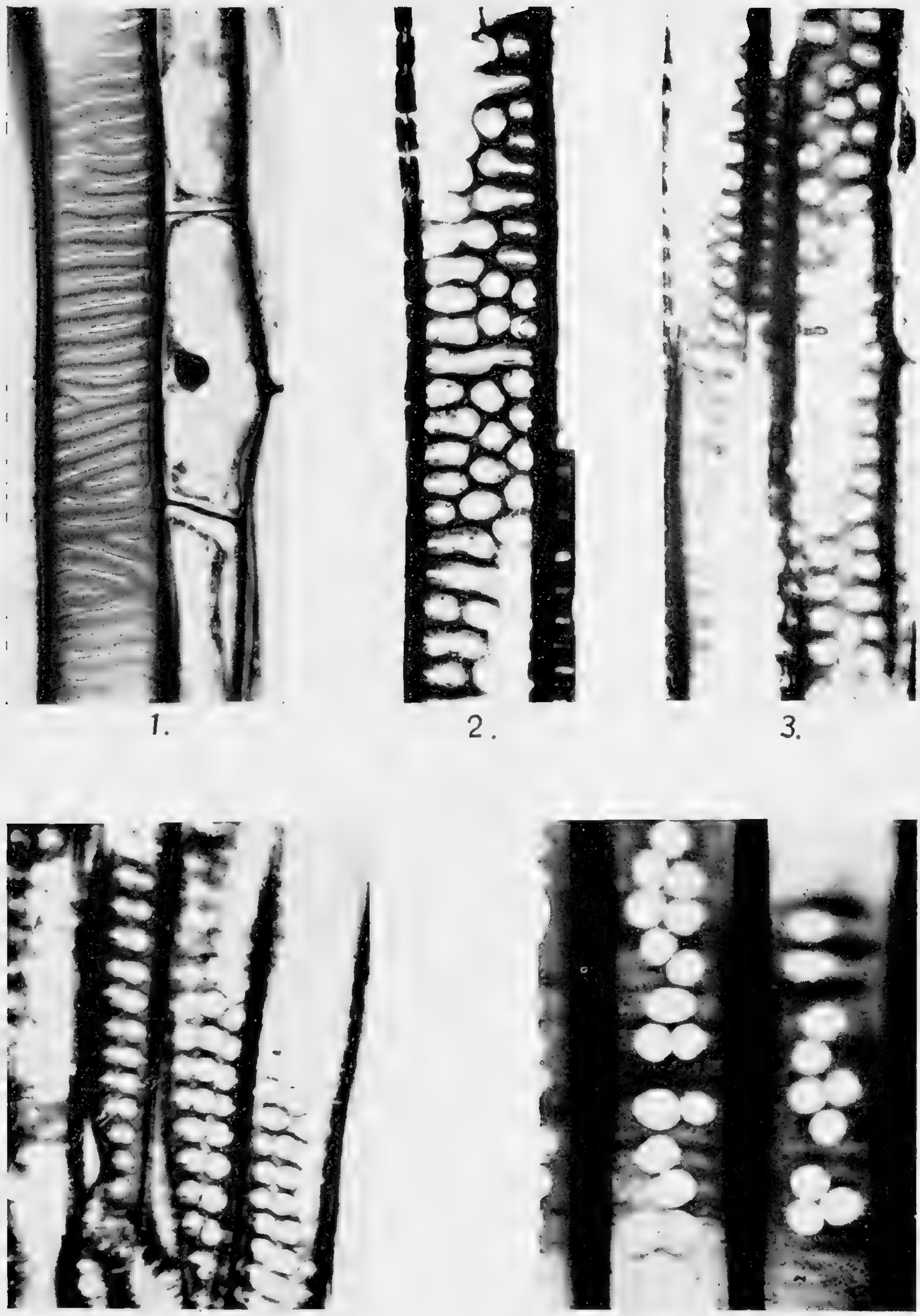
Fig. 27.—*Ginkgo biloba*, radial of stem. ×432.



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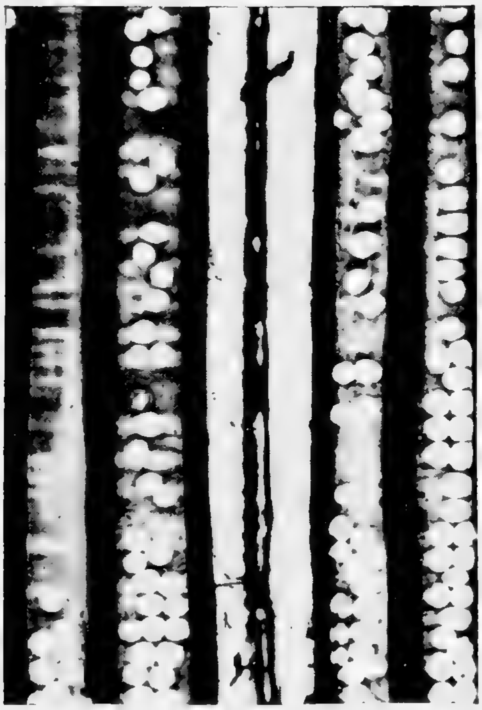

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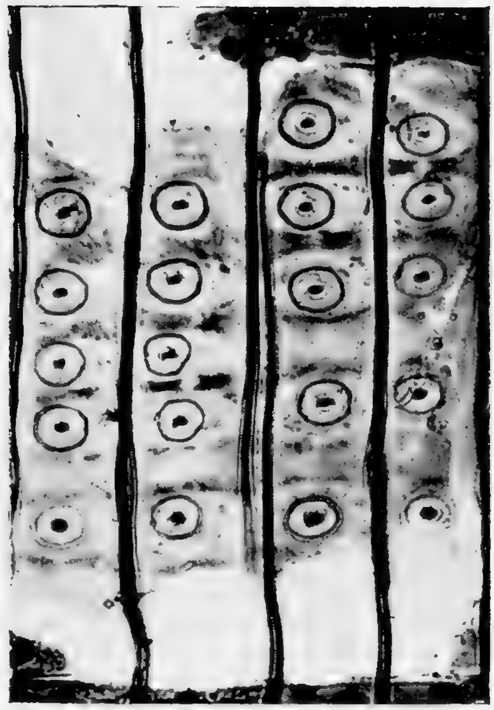

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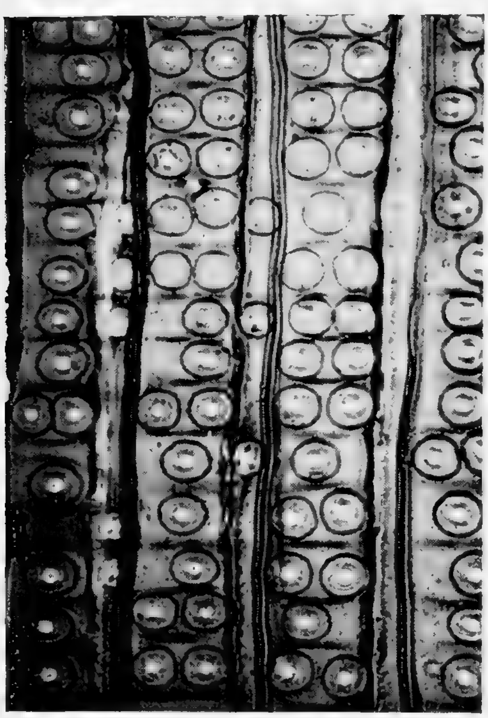

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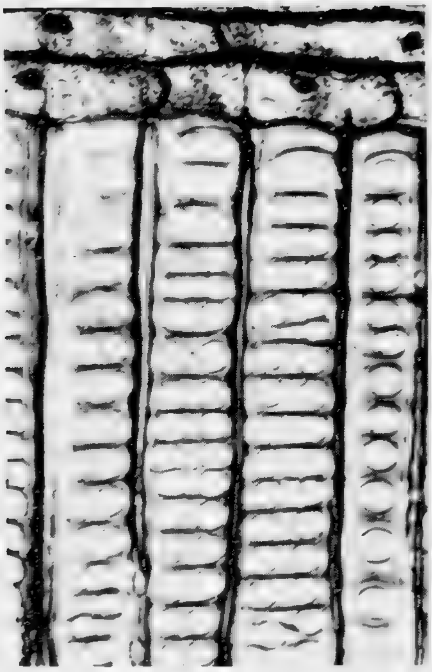

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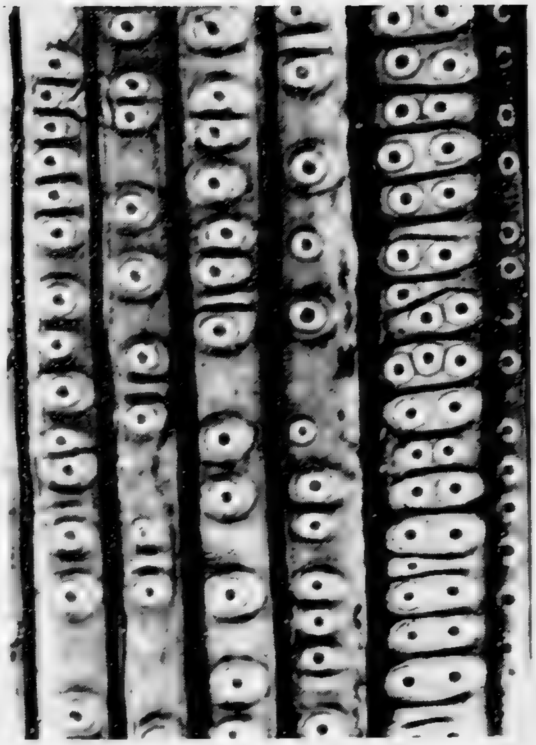

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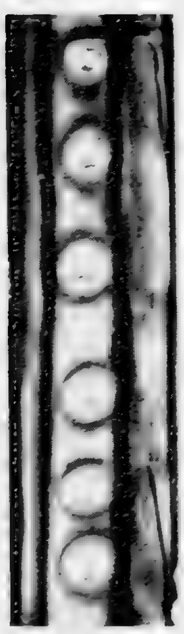

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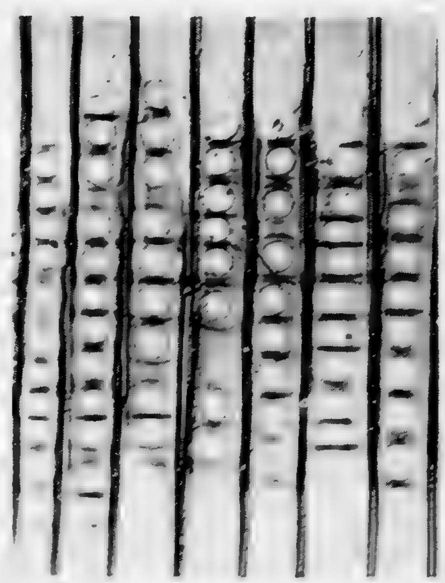

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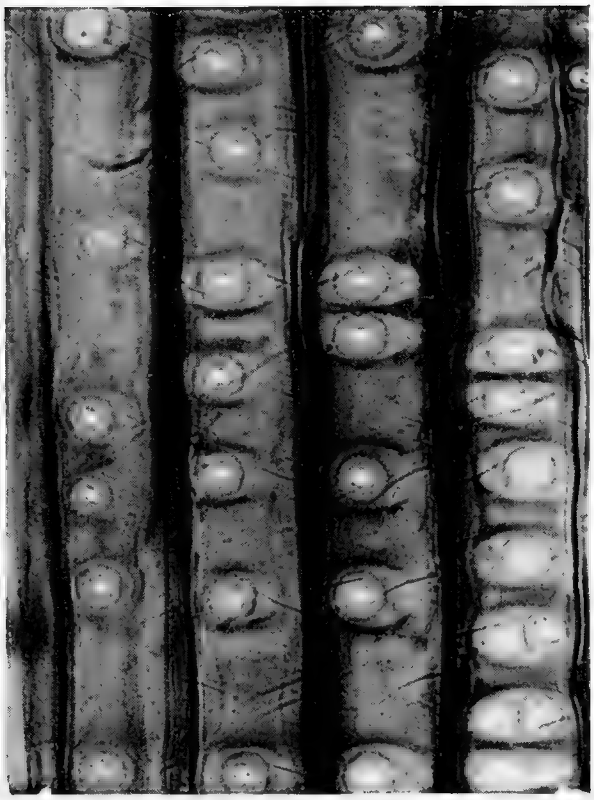

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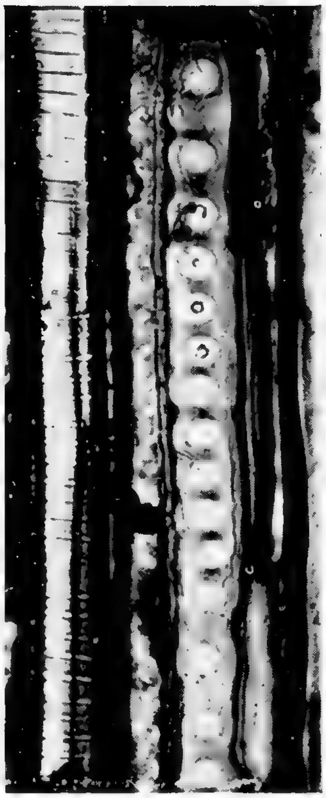

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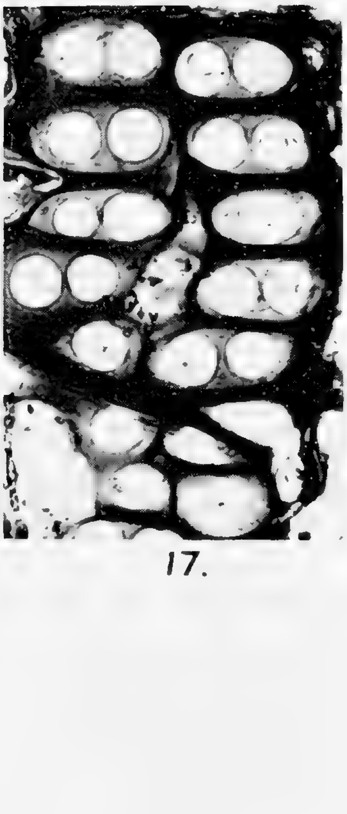

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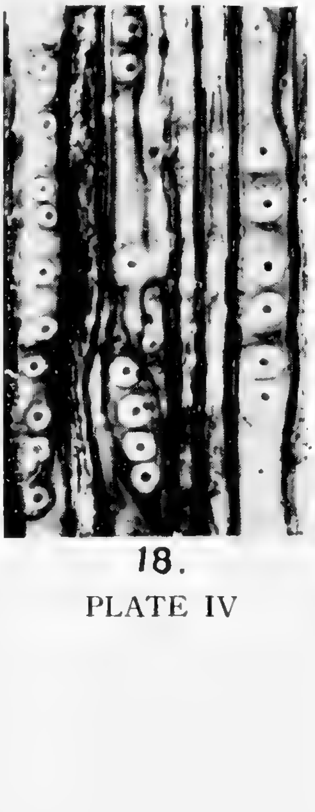

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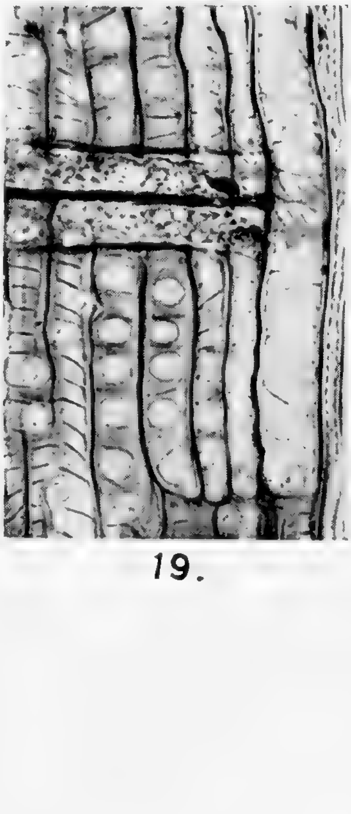

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PLATE IV

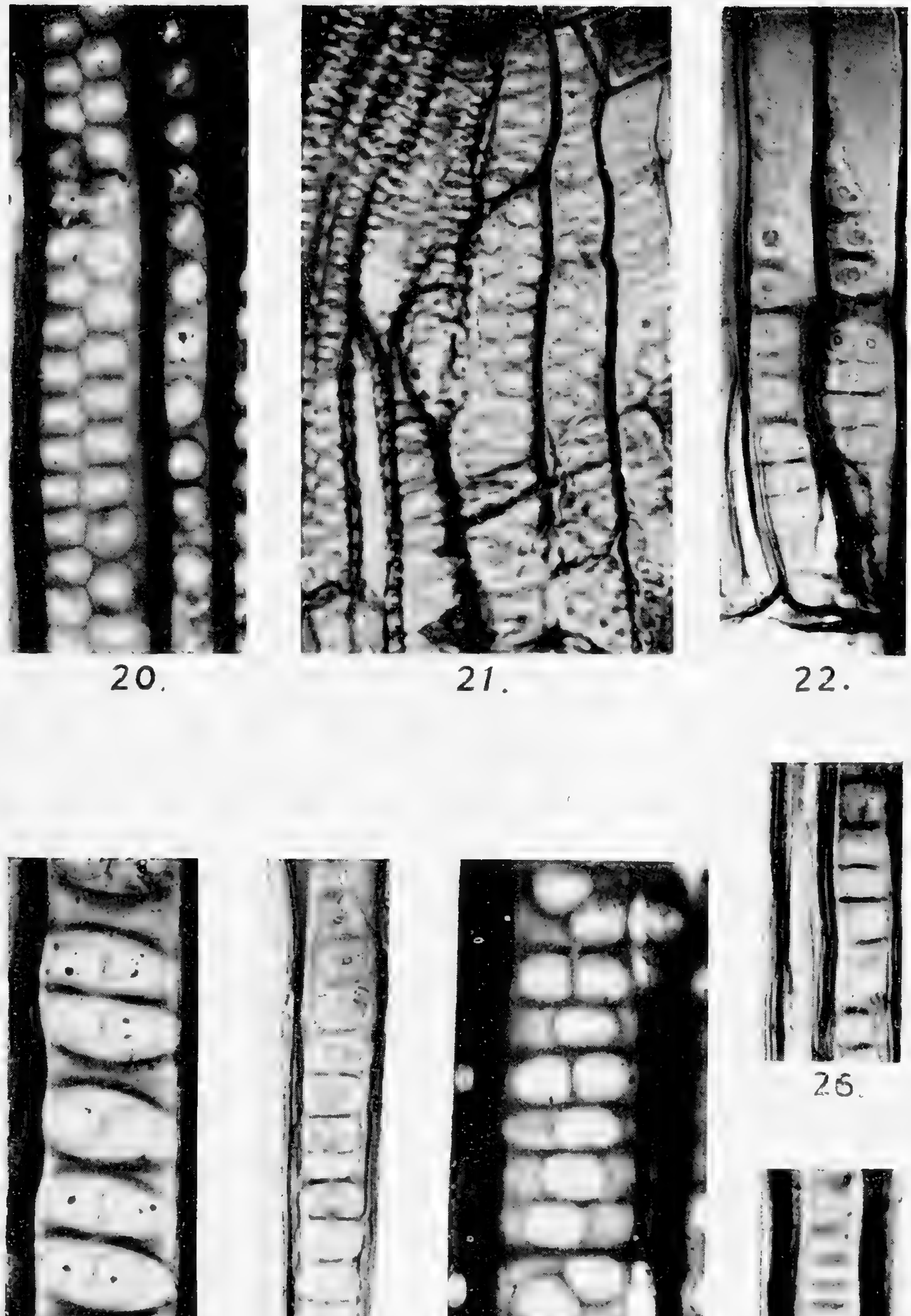

PLATE V

XVI. *The Red Discolouration of Cured Codfish*

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(Read May Meeting, 1922)

CONTENTS

I. THE CODFISH INDUSTRY.

The codfish industry provides for the Dominion of Canada a return of no inconsiderable amount—one which surpasses that derived from all other fish enterprises, salmon alone excepted. In figures, the total quantity of cod caught and landed during 1919 was 2,606,770 cwts., which, when marketed, yielded a return of $9,987,612.

The fish is marketed in a variety of forms, such as fresh, green-salted, smoked fillets, smoked, boneless, canned, but by far the greatest amount as dried cod. From the total catch of cod in 1920 823,000 cwts. was sold as dried, green-salted, or boneless, and the quantity exported up to the end of the fiscal year ending March 31st, 1921, was 713,000 cwts., providing a return of $5,169,266.

Practically all of the dried fish prepared in Canada is exported. About one-eighth of it finds a market within the British Empire, while the remainder goes to foreign countries, where it is purchased in amounts varying from 6 cwt. to 186,933 cwt. It is unnecessary to mention the various countries to which this product is shipped; suffice to say, they are numerous and widely scattered. Incidentally, greater amounts are sent to the United States than any other one country.

In recent years dried codfish along the Atlantic Coast has become infected in such a way that the surface of the fish acquires a distinctly pink or red colour. This, naturally, detracts from the wholesome and palatable appearance of the fish and causes an unmarketable product, which, obviously, is a loss to the trade. Complete figures for such loss have been unobtainable, though individual dealers estimate their personal deficits from two and a half to forty per cent.

One of the largest curers of, and dealers in, dried fish in Nova Scotia, handling not less than 100,000 cwts. annually, informed the Department of Marine and Fisheries that in one season they had 3,000 cwts. affected with reddening, but this quantity was looked upon as unusual.

As a rule, the exporter is the individual who stands the reddening loss, owing to the fact that colour does not appear until after storage in warm surroundings or in tropical climate. The fisherman really stands the loss, however, by reduced prices the following year in order to reimburse the exporter.

The infection, though comparatively new to the Canadian trade, has existed at various times, and in different countries for, at least, the last forty years, during which time investigations as to the nature of the discolouration have been carried on rather from a scientific, than from an economic, standpoint. In the past the fish was marketed usually, during the colder months of the year, so that there was not so large a percentage of spoilage as prevails to-day; and whatever loss dealers did experience from reddening was regarded more or less as incidental and unpreventable. Not so to-day. Progressive civilization demands not only increasing attractiveness in food displayed for sale, but also a product procurable at all seasons of the year—preferably out of season. This necessitates infinite care in preparation, requiring additional labour, and adding to the expense of production; but more than that, fish marketed during the warmer months of the year seems more susceptible to the red infection than that marketed during the colder months. To-day dealers are alarmed at the loss from this source, and anticipate a satisfactory remedy. Consequently, we are confronted with a problem of considerable economic importance.

Another factor which must be mentioned is the increasing competition from Norway in the world's markets. Where such competition is keen it is of utmost importance to provide a fish which is well cured, attractive in appearance, and which is not affected in any way by any kind of discolouration. The country which succeeds in putting up the best article and keeping it uniform from year to year will undoubtedly secure a larger trade and obtain the higher prices.

As has been intimated, a number of investigations have been carried on in order to determine the cause of the discolouration of codfish occurring in other countries, hence a short historical account of these researches is necessary.

II. Historical Resumé.

The occurrence of red colouration on food stuffs is of extreme antiquity. Down through the ages we have many references to food becoming red or bloody, and whilst this colour usually has been ascribed to the well known *Bacillus prodigiosus*, it is most probable that many forms were responsible for the coloured conditions described by writers previous to the bacteriological era.

Thus Lucan, in one of his dialogues, makes Pythagoras give, as the reason for forbidding his followers to eat beans, the fact that white beans, if placed in the moonlight, change into blood. In the year 332 B.C. (1) Alexander the Great experienced an outbreak of bloody bread at the siege of Tyre, and as the blood was on the *inside* of the bread, the augurs allayed the fears of the soldiers by the interpretation that a bloody fate would fall on those *inside* and not on the *outside* of the city.

The phenomenon of the "bleeding host" was frequent during the middle ages and as the popular explanation of the phenomenon was that witches or unbelievers were the cause, numerous murders and executions followed, which caused the remark of Scheurlen that this saprophyte (*B. prodigiosus*) had caused more deaths than many pathogenic bacteria.

1819 the Province of Padua was set in commotion by the frequent appearance of red spots on various articles of food.

The reddening of salted and dried codfish has been known for many years. Mauriac has mentioned references to this discolouration in an old almanac published in 1838.

The first paper of scientific interest, however, must be attributed to the late Dr. G. W. Farlow, Professor of Botany in Harvard University.

The redness of the codfish examined by Farlow (2) appeared after the fish had been landed from the vessel, but in some cases the fish became red while in the vessel. A microscopic examination showed that the redness was due to a minute plant, known by the name of *Clathrocystis roseo-persicina*, which consisted of a number of minute cells filled with red colouring-matter and imbedded in a mass of slime. This schizophyte did not increase rapidly at a temperature below 65° Fahr. The plant was found in the packing-houses, on walls, floors, and the flakes on which the fish were laid. Farlow notes that the salt used at Gloucester came from Cadiz and Trapani. The Cadiz salt had a rose-coloured tinge, and he found in it considerable quantities of the same minute plant that he found in the red fish. The Trapani salt was pure and he does not specifically state that he found the organism in it. He considers that the fish was infected by means of the salt, favoured by warm temperature.

Another organism found by Farlow on the red codfish was an organism which appeared in fours, and which bore a strong resemblance to *Gloeocopsa crepidinum* Thuret. This organism he described under the name of *Sarcina morrhuae* n. sp.; cells colourless, cuboidal, 5-8 μ in diameter, united in fours and surrounded by a thin hyaline envelope; colonies 10-20 μ in diameter, formed by division of the cells in three dimensions; colonies heaped together in irregularly-shaped, lobulated masses.

Later a notice (3) of the *Clathrocystis* and *Sarcina*, together with a description of a third species *Oidium pulvinatum*, Farlow, was published in the *Revue Mycologique*.

In 1886, Farlow (4) published an account of further cases of reddened codfish appearing in European journals. Bertherand (5) gave an account of poisoning that occurred among troops at Sidi-Ben Abbes. The fish, of Newfoundland origin, had a vermilion colour extending from the surface into the flesh. The colour was attributed by Megnin (6) to the growth of a fungus which he named *Coniothecium bertherandi*. The editor of the *Revue*, Roumeguere (7), raised the question of the identity of the two species described by Farlow and Megnin.

Subsequently specimens of reddened fish from Bordeaux and Dieppe were received by Roumeguere and the colour ascribed to the presence of *Clathrocystis*.

Poulsen (8) found on mud, near Copenhagen, a Sarcina which he named *S. littoralis*, which, upon exchange of specimens, was found to be identical with *S. morrhuae*, and on account of the date of publication the name *littoralis* had priority.

The nomenclature was further complicated by Saccardo and Berlese (9), who considered the *C. bertherandi* of Megnin to be identical with *S. littoralis*, which they state is considered by Zopf a condition of *Beggiatoa roseo-persicina*, under which name Zopf included *Clathrocystis* as a zoogloea form. Farlow disagreed with Zopf's opinion on the grounds of difference in colour, size and conformation.

Layet (10) described the *Coniothecium* of Megnin as follows: "Round spores of very pale rose colour, with granular contents, and a small kernel measuring 6 to 10 micra in diameter, the largest of these spores are divided into two or four equal parts, which become new spores; a short mycelium, hardly discernible, in most of these diminutive spores."

Besides the poisoning mentioned by Bertherand, several other cases are mentioned in the literature, of supposed toxic effect due to ptomaines produced by the chromogenic organism or perhaps due to a secondary agent not isolated or identified. Thus Schaumont (11) in Algeria reported an outbreak in which one hundred and twenty men were poisoned after a meal of spoiled fish. Berenger Feraud (12) reported other cases.

Mauriac (13) gave a brief review of cases of poisoning caused by spoiled codfish, seven in number, of which the more important are mentioned elsewhere. In four of the seven cases the fish did not show red discolouration, but even in the cases where red colour was present there were unmistakable signs of putrefaction as evidenced by a putrid odour and crumbling of the flesh. The nature of the red substance was investigated at Mauriac's suggestion by Carles and Gayon of Bordeaux, who found on microscopic investigation of the red spots that numerous organisms, and particularly micrococci were present. They dissolved some of the red matter in some drops of boiling water and transferred the liquid obtained to codfish broth and moist pieces of cod, and after incubation at 30° to 35°C. red colour developed and covered all parts exposed to the air. Finally, the number of living agents was reduced to two, a bacillaria and a micrococcus, which, when mixed, invariably produced the red colour, although the respective part each organism took could not be determined. Comment was made on the remarkable fact that these organisms could live on sea salt, and develop on moist salt crystals.

Reference is also made to investigation at the Bordeaux Medical School by Layet (14), Artigalas and Ferre, who found amongst other substances Sarcines (quarters of a sphere joined by a common diameter), and who attributed the red colour to the sarcinoid elements.

Experiments made by eating reddened fish, and feeding it to dogs and rabbits, gave negative results. An interesting note in a popular almanac for the year 1838 stated that red codfish was at that time considered the best, and that in the Antilles and Reunion consumers gave preference to red codfish, which they term "saumonée."

In the resumé the author definitely stated that "red colour is no indication of injurious character, because it is a well established fact that from time immemorial people have eaten red codfish without experiencing any bad consequences, and because animals (dogs and cats) have for several days in succession been fed on raw codfish having a red deep colour, without causing any sickness whatever."

Dumas, another doctor quoted, stated that the rose colour showed itself most frequently when Mediterranean salt had been used, whilst salt from the west of France produced a contrary effect. Carles was also of the opinion that the origin of the trouble was in the salt.

The nature of the poisonous substance was in all probability a ptomaine, possibly gedinine obtained by Brieger from codfish, and as Mauriac's article was essentially a hygienic one a very full discussion of meat poisoning is given.

Samples of dried cod, some of the tissues of which had assumed a light reddish colour, were examined by Ewart (15). They had been sent from Lerwick, and several tons were found to be affected on reaching their destination. From inquiries made in the district, Ewart ascertained that a similar discolouration had appeared in the preserved cod some fifteen or sixteen years previously. The cod was investigated by bacteriological methods by Edington (16). Sections showed only micrococci. Portions of the red fish were fed to mice without untoward results.

Plate cultures were made in beef peptone gelatine and resulted in the isolation of eight organisms, none of which produced colour.

By culture on bread paste inoculated with red fish and red salt a red growth was obtained, which proved to be a small bacillus, non motile, 0.3-0.5 μ thick and 1.5 to 4 μ in length. Threads were formed and also spores, which measured 1 μ in length and 0.5 μ in diameter. It did not grow well on gelatine at room temperature, but better at higher temperatures when it formed a thick pellicle on the liquefied gelatine, pink in colour on the lower surface. No colour on agar; pink to red on bread paste.

Four illustrations are given showing rods, spores and threads. Two figures show cocci in the preparation.

No information is given as to the possibility of the growth of this organism on salted cod, or salt media.

Le Dantec (17) described two degrees of redness, the first healthy red cod, characterized by a red, non-viscous layer, easily lifted, and which revealed healthy and firm muscular flesh beneath. Microscopically algae, bacilli and cocci were present. The second degree he called altered red cod, characterized by a viscous red matter, with an alkaline reaction and a nauseating odour. Microscopically cocci, associated with a Sarcina-like organism, which occurred in groups of four, were present. In a moist chamber the alteration from the first to the second degree would be accomplished in two to three months.

Le Dantec considered that the algae present, which he was unable to obtain in pure culture, was the same organism described by others under the various names of Clathrocystis, Protomycetes and Algae, and that it had nothing to do with the red discolouration.

In a petri dish made with gelatine and left for two or three months Le Dantec found a red colony which was that of a motile bacillus, with a spore at one end. Thereafter he used two methods for obtaining red colonies. The first, he diluted a portion of the red cod in a drop of broth, and made gelatine plates from this material. At the end of two months he cut out pieces of the gelatine which had no growth, and made a second plate; at the end of eight days he obtained fine red colonies of the bacillus in a pure condition.

The second method of isolation was by means of heat. Relying on the resistant nature of the spores, he submitted some of the red material broken up in sterilized water to the action of heat at 95°C. for a minute, and then made plates and obtained his red organism in pure culture.

The red bacillus was of variable size. On codfish it varied from 4 to 12 μ or more in length, motile, with a terminal spore. Colonies appeared as discs, pale red in the centre and darker at the margins. Occasionally the red colour was uniform. The colony was full grown in 12 days, when it was about two millimetres in diameter. It gave a slow, funnel-shaped liquefaction in stick cultures, reddish in colour; less colour on sloped agar. In broth it gave turbidity and a greyish colour. On potato it grew badly. The colouring matter was more abundant when grown at 10-15°C. than at incubator temperatures. Sterilized codfish reddened less well after inoculation than fresh cod.

Le Dantec noticed that the red colour was more intense on the *salted side* of the cod, and fewer spores were produced than in artificial media. It was non-pathogenic to animals. The name suggested was the red bacillus of Newfoundland.

Other organisms isolated from the red codfish were:

(1) A coccus which only produced red when associated with a small liquefying coccus.

(2) A red yeast (*Rosa hefe*) which reddens the codfish at incubator temperatures.

(3) A red mould which gave rise to small irregular pigmented granulations.

(4) A yellow coccus, 2-3 μ in diameter, which does not liquefy gelatine.

(5) An orange coccus, 2 μ in diameter, non-liquefying.

(6) A rusty coccus, 2 μ in diameter, which gave colonies resembling rusty iron in colour, made up of concentric circles alternately dark and pale red.

Attempts to isolate the red organism from salt failed, and Le Dantec did not believe that it was a factor in the origin of the red colour.

Matzuschita (18) investigated the tolerance to various percentages of salt of a number of pathogenic and non-pathogenic bacteria, none of them were halophylic, and 10 per cent. salt was the highest concentration tried.

Matzuschita concluded that the influence of salt added to agar was very variable; that whilst several species supported the addition of 10 per cent. without undergoing morphological changes, many produced striking degeneration forms with much less quantity of salt.

Keilesj (19) employed salt media up to 20 per cent. and noted only morphological changes due to different degrees of salinity in cultures obtained from herring brine.

Höye's (20) first two papers were concerned with moulds and especially *Torula epizoa* on dried codfish, with the part played by salt from various localities, the infection of storage houses, and methods of disinfection, etc. A few remarks about red codfish are found in these two publications.

The greater part of Höye's (21) third paper is concerned with *Torula epizoa*, *Torula minuta*, and the presence of the spores of these organisms in the air. Other organisms mentioned are *Sarcinomyces islandicus*, found on fish coming from Iceland and the Faroes, which did not affect the fish nor produce a disagreeable odour or taste. *Sarcinomyces niger*, occasionally found. *Sarcinomyces sporigenus*, extremely rare.

Three species of yeast (A, B, Y), varying in size from 3 μ to 6 μ, growing well in salt media, with an optimum salinity of 10 per cent., the cells becoming larger with increase of salt content. No colour produced. Three species of bacteria are described, a coccus producing a yellow to yellowish red pigment, a second coccus giving a wax yellow colour and a non-chromogenic bacillus. All of these were halophilic, optimum salinity 10-15 per cent.

In the resumé, Höye stated that there was no doubt that under the name of red bacteria there were at least two species concerned—a medium-sized sarcina and a micro-coccus, and a species described by Olav Johan-Olsen, named *Sarcina rosacea*, smaller in size than that seen by himself.

In all probability there were three species, but Höye did not know which was the most dangerous. He found the red sarcina only once on some Norwegian cod, and at the same time in large numbers in a salt shop at Bergen. The micro-coccus had been found several times in samples of salt coming from various stores.

Höye considered that the various methods of handling salt cod tended to produce different results—the French method of handling favouring the development of the red bacteria, and the Norwegian method of drying their product resulting in the growth of *Torula epizoa*.

Höye (22) examined some 36 samples of salt from Lofoten, especially to ascertain the number of spores of *Torula epizoa* present. He found other organisms on twelve of these samples, red bacteria, Micro-coccus B, Bacillus Y, and also *Sarcinomyces islandicus*. The presence of the red organism he regarded as suspicious and deserving the attention of fish curers. A hasty examination showed that the red form was an oval coccus, 1 μ in diameter, and which formed on 17 per cent. salted meat small red slimy colonies.

Höye also examined thirty samples of fish for *Torula epizoa* and red bacteria. Nine of these samples gave red bacteria on salted fish. The red organism grew in small, raised, irregular, round, intensive red colonies, always grew on the surface and never in the tissues of the fish. Microscopically this red organism was a slightly oval capsulated coccus, about 1 μ in diameter, often appearing as a diplococcus. In all probability it was identical with the form found in salt.

Its growth was extraordinary slow, on fish at room temperature often taking several months.

Beckwith (23) isolated, during the summer of 1907, a diplococcus from reddened fish. This organism, which he named *Diplococcus* *gadidarum*, was a small organism 0.4 to 0.5 μ in diameter, growing larger by repeated cultivation. It stained readily with all common stains, Gram positive, non-motile, aerobic, grew feebly on standard beef agar, did not grow in other ordinary laboratory media. On special media made with codfish the colony was 1 to 2 mm. in diameter, edge regular and slightly raised, salmon pink in colour with the edge whitened. Grew in 15 per cent. salt, but not in 20 per cent., best growth on 5-10 per cent. salt.

Beckwith produced the characteristic pink colour on tubes of shredded fish and obtained it again in pure culture from this pink material. This organism was prevalent in 1907 and 1910 at Gloucester, Mass.

Bitting (24) has given a full account of his investigations at Gloucester. The colouration varied from pale pink colour to bright red. The more intense colour appeared when the fish was drier and the germs formed thicker spots. The redness occurred on all parts of the fish, including the skin. Spoilage at the factory was limited to the months of July, August and September, and did not appear in the cooler months.

The source of infection was not fully determined. The organisms probably had a normal habitat in the salt water and the lowlands along the coast, and grew freely upon fish or wood that is salty. Red organisms were obtained from salt from the hold of a salt steamer, and from the salt in a store house. This salt was solar sea salt, and came from either Trapani (Sicily) or Iviza (Spain). Formerly Cadiz salt was used, but the change was made to the two former when it was believed that the reddening was due to Cadiz salt. 25,000 tons a year are used at Gloucester.

In nearly all cases examined there were three organisms found: a coccus, a bacillus, and the cells of a mold-like fungus. Where the last was present brown spots formed, distinct in appearance from the reddening.

The red growth was very viscous, the material drawing out in fine threads. In the pink spots this was less noticeable than in the older and redder spots. When mixed with water the pink growth became very viscous. The viscosity made separation of the organisms very difficult and no dilution was used in making plate cultures directly from the fish.

The coccus was the organism which produced reddening in cultures and on the fish. It was variable in size from 2-5 μ in diameter, averaging 2 to 2.5 μ. Many times a pair was found composed of a large and small coccus, or a tetrad with one, two or three large ones joined respectively to three, two or one small ones. A divisional line sometimes showed in a large cell. No spores were found. No motility and no flagella were noted. Capsules formed and were visible in stained and unstained preparations. Stained readily with all the usual stains. On solid media a viscous mass was formed which pulled out with the needle. Zoogloea masses formed on the surface of liquid cultures. Colour varied from pink to bright red. Colour was not affected by alcohol, chloroform, weak ammonia and potassium hydrate, but disappeared in weak acetic acid when taken from cultures, but more sensitive when obtained direct from fish. Strictly aerobic.

It grew well in beef bouillon, milk, gelatin and agar giving red growth; no liquefaction of gelatin; growth delayed by 5 per cent. salt, considerably so by 10 per cent. and no growth in 15, 20 and 25 per cent. salt media. It grew well in bread paste, forming a bright red waxy growth. It also produced pink colour on sterilized rice. In codfish broth there was less abundant growth than on beef gelatin.

Optimum temperature 72-75° F. Good growth but less at 90°-95° F. and very slight growth at 44°-50° F.

The bacillus was a large one, 5.7 μ long and 0.9 to 1.3 μ in diameter; grew well on all laboratory media, but produced colour, a pink tint, only on bread paste.

The fungus is similar to that described by Farlow, but other stages in its development are noted.

A number of inoculation experiments on fish were carried out. Fish sterilized by heating were inoculated, but the fish spoiled by softening and became foul before the germs causing the reddening had time to develop. Afterwards raw fish was used, placed in covered glass dishes. Inoculations with the coccus at room temperatures gave spots a millimetre in diameter in two to three weeks at room temperature. In about five to six weeks reddening developed, usually at places on the fish other than the points of inoculation.

When coccus and bacillus were used together, general reddening followed, sometimes at other points. Control pieces remained free from reddening in most cases. It occurred, however, at times but later than was the case with the inoculated pieces.

Partially paraffined fish was also used with results similar to the above, but no reddening under the paraffin.

The author concluded that the coccus was the organism which produced the reddening.

Note should also be made of the foul odour which accompanied the reddening.

Bitting was of the opinion that the reddening was due to factory infection, the use of contaminated water and to methods of handling. The amount of infection due to the use of solar salt was not definitely determined, as in the experiments intended for that purpose the amount due to factory infection was not wholly eliminated.

Pierce (25) attributed the reddening of the brine from salterns to red chromogenic bacteria. The particular organism was a bacillus 3.2 μ to 3.3 μ wide by 3.4 μ to 3.6 μ long. On salt agar it formed raised colonies ranging in shade from pink through clear red to crimson according to the size of the colony On agar slopes the pigment diffused more or less through the agar imparting to it a fine and delicate shade of pink.

Pierce secured a piece of Georges Bank codfish with pink discolouration and produced red growth on salt agar. When he inoculated sterilized salt codfish with the red culture from brine agar he was not uniformly successful and he attributed his failure to the use of preservatives used on certain lots of salted cod. He concluded that this organism was present in salt after it was harvested and stored and would produce red colouration if brought into contact with codfish. He suggested sterilization of the salt to prevent infection.

Kellerman (28) described two cocci isolated from red codfish. One he considered identical with *M. litoralis* (Poulsen), *Clathrocystis roseo-persicina* (Farlow), *Diplococcus gadidarum* (Beckwith), and he thought that Beckwith was working with a mixture of this organism and a smaller micrococcus and suggested that the name *M. litoralis gadidarum* be retained for the smaller organism. Both organisms were slow growing and required ten to thirty days at 25° C. to make visible growth on salted fish. Both organisms grew in 15 per cent. salt codfish agar, also slightly in beef broth and milk, and the larger one grew well on beef gelatin and agar, the smaller one gave scanty growth. Both organisms stained well with methylene blue and were gram positive.

The red colour on salt fish penetrated the meat and gave to the centre a red tint.

Cobb (26) stated that codfish was subject to spoilage when exposed to a temperature above 65° F. Spoilage usually manifested by the fish turning red and emitting a foul odour. Fish completely submerged in pickle was immune so long as it remained there. The trouble was not so marked on the Pacific coast, due probably to the lower summer temperature of this coast and the use of a higher grade salt. Cold checked the growth of the organisms and bleached any colour that might be present.

Browne (27) stated that the development of red colouration was due to the growth of two micro-organisms whose probable origin is the sea salt in which the fish are cured. His summary is as follows:

1. The reddening of salted fish is due to the growth of two distinct micro-organisms, a spirochete producing an opaque pink colouration and a bacillus producing a transparent red colouration.

2. These two organisms grow in such close harmony that the colouration of fish may vary from the pale pink of the spirochete to the dark red of the bacillus. Likewise their separation into pure culture is very difficult.

3. The optimum concentration for growth seems to be saturation, growing well on heavily salted fish, brine, sea salt, and fish agar media saturated with sea salt.

4. No growth appeared on media containing less than 16 per cent. sea salt by weight.

5. The morphology of both organisms depends upon the concentration of salt in the medium, varying from the largest forms (14 micra) found in heavily saturated media to the spherical forms (2 micra) found in media of 18 per cent. concentration, with all intermediate forms. The amount and character of the colonial growth does not seem to be affected by the varying concentrations of salt.

6. Due to their great sensitiveness to changes in density, staining of these organisms is very difficult.

7. Their optimum temperature for growth is about 50° to 55° C.

8. Both forms are strictly aerobic.

9. Sunlight is not germicidal to these micro-organisms as both will tolerate long exposure (8 hours) to the sunlight or electric light.

10. Influenced by age, low temperatures, and metabolic products these organisms suffer a temporary loss of pigment which is closely associated with the formation of bodies similar to the coccoid bodies of the spirochetes. By transplantations pigmentation, along with vegetative forms, is resumed.

11. All results indicate that the probable source of these micro-organisms is the sea salt in which the salt fish are cured and any method devised for the elimination of this reddening from the salt fish industry must be based upon the proper disinfection of the sea salt.

As it seems important to know whether the organisms isolated by various authors mentioned above can grow in media containing large percentages of salt, and in order to show whether they all reproduced the trouble on salted codfish, the following summary is given:

Author	Organisms producing redness	Halophilic growing in at least 10% salt media	Inoculation experiments on salted cod	Solar salt indicated as cause	Optimum Temp. C.
Farlow	Clathrocystis roseo-persicina	No	None	Yes	..
Farlow and Poulsen	Sarcina litoralis	No	None	No	..
Megnin	Coniothecium bertherandi	?	None	No	..
Carles and Gayon	Micrococcus and a Bacillus together	No	None	Yes	..
Layer and others	Sarcina	No	None	No	..
Edington	Bacillus rubescens	No	None	No	30
Le Dantec	Red Bacillus of Newfoundland	No	No	No	20
Höye	Sarcins, medium sized	Yes	No	Yes	..
Johan Olsen	Sarcina rosacea	?	?	?	..
Beckwith	Diplococcus gadidarum	Yes	Yes	..	?
Bitting	Coccus	No	Inconclusive	Inconclusive	23
Pierce	Bacillus	Yes	Inconclusive	Inconclusive	..
Browne	Spirochete Bacillus	Yes	Yes	Yes	50-55
Kellerman	M. litoralis var. gadidarum	Yes	Yes	Yes	25?

III. The Present Investigation

1. *Description of Colour on Salted Fish.*

Through the co-operation of the Marine and Fisheries Department at Ottawa, and the courtesy of various fish inspectors and dealers throughout the Maritime Provinces, samples of reddened cod were obtained from various localities, such as Digby, Antigonish, West Pubnico, Pictou, Annapolis, Harbourville, Canso and Arichat in Nova Scotia, Grand Manan and Campobello in New Brunswick, and Souris in Prince Edward Island. A large number of samples were also obtained through dealers, the source of which was not noted. In all, thirty or forty samples of fish were received. Some of the samples showed definite signs of decomposition, which occasionally had advanced so far that the red discolouration was not distinguishable from the rusty brown colour of the partly decomposed flesh. Such samples were not kept for investigation. Of the fish examined the red appeared in varying intensities and amounts, from a sample where the flesh presented a very delicate pink mosaic appearance, to one where the surface of the fish was entirely covered with a dark rose-red growth (roseus, Saccardo)—and even the salt crystals adhering to the fish were pink in colour. In some cases the pink or red discolouration penetrated between the flakes of the flesh. Most of the samples submitted were pieces cut off the fish, but in the majority of cases where the whole fish was sent the colour was more pronounced along the backbone. In no instance did the colour penetrate the flesh of the fish except where the skin was cut or broken apart, and then did not extend beyond the surface of the fissure. It was very definitely surface growth, which developed equally well on either the white flesh or on the skin of the cod; upon the latter it was particularly noticeable in folds of the skin, where there was a certain amount of moisture, and here the colour was invariably a clear cherry red (Carmine, Ridgway) collecting in drops. On the front of the fish or on parts of the skin, where there was not so much moisture, the colour was more pink than red. The fungus *Torula epizoa*, described by Höye, was present on a number of fish, occurring as black spots on the skin, and on the thinner upper parts of the fish.

2. *Direct Microscopical Examination.*

Microscopical examinations were made directly from each sample of fish received, and although various organisms were found the preparations showed more or less similarity. Occasionally small cocci, averaging less than 1 μ in diameter, and without exception, rods of varying size, were seen. Frequently the rods were long and slender, measuring from 3 μ-7 μ in length, and 0.5 μ in width, some slightly bent, while again shorter and thicker rods, about 2 μ in length and 1 μ in width, appeared, but the average rod measured about 3 μ. Practically all of the slides showed the presence of torula-like or amoeba-like forms, and many irregularities in shapes and sizes, such as oval, egg-shaped, pear-shaped, or lemon-shaped, and varying in size from 1 μ-4 μ, but averaging about 2 μ. Very often they appeared in pairs, the longer axes being parallel, and the adjacent sides flattened. Two or three fish showed bodies which resembled *Placoma* (Engler-Prantl) (19). The cells were as large as 5 μ or 8 μ in diameter. They were generally rounded in shape, showing one segmentation, which divided the cell into two hemispheres, separated by a clear zone. Occasionally another segmentation, at right angles to the first, making three, and not infrequently four divisions, separated by clear spaces, was observed. The fresh preparation showed no colouring matter, so that, evidently, it was a species of *Schizophyceae*. These bodies resembled in shape (but not in colour content) those illustrated by Le Dantec, and thought by him to be the same as *Clathrocystis* (Farlow).

None of the organisms found, except cocci, stained satisfactorily with the ordinary aniline stains, and Gram's method no better than any of the others. Heated methylene blue gave the best results until Jenner's, Leishman's, Wright's and Giemsa's stains were tried, when Giemsa's proved to be much better than any of the others. Rose-bengal in 5 per cent. carbolic acid gave fair results. The difficulty in staining was largely due to the impossibility of making preparations on the slide. When the material was transferred to a drop of water it became slimy and sputum-like (plasmoptysis). After fixation with heat the stain did not take hold, and the preparation often washed off. Various substances were tried instead of water, such as ether, xylol, chloroform, alcohol, acetic acid, methyl alcohol, and so forth. Of these, the last two gave the best results, but acetic acid had a tendency to precipitate the material. The most satisfactory preparations were obtained with 16 per cent. solar salt solution, dried, fixed in equal parts of ether and absolute alcohol, or in absolute methyl alcohol, and stained with Giemsa. These preparations were often spoiled by the salt crystals, either from their remaining on the slide, or from the organisms collecting in great masses immediately around the crystals. Fixation with heat not only gave poor results, but the organisms were noticeably smaller. With Rose-bengal, some very clear but lightly stained preparations were obtained; the organisms were, however, appreciably smaller when compared with similar preparations made with Giemsa. These remarks on staining are equally true of the conditions experienced when making preparations from cultures from the various media employed.

3. *Isolation of Causal Organism.*

The first sample of fish received came from the Digby office of the Maritime Fish Company. The pink colour was in spots over the entire surface of the fish, and even the salt crystals adhering to the coloured parts were decidedly pink. Two pieces of fish, where discolouration had started, were cut off and placed in moist chambers, one kept at 22° C., the other at 37° C. In both cases colour spread over the entire surface, the only difference being that at 37° C. the colour was much deeper than at 22° C. Numerous attempts to culture the organisms on artificial media, however, were, at first, unsatisfactory. Ordinary laboratory media, such as nutrient agar, sugar agars, nutrient gelatine, beef broth, sugar broths, cider, milk, and potato slants in varying percentages of salt were inoculated directly from the fish, and also from dilutions of the pink material in 16 per cent. solar salt solution, but no growth developed. Fish slants, similar to potato slants, were tubed in varying percentages of solar salt—(2, 4, 6 to 18) sterilized, and then inoculated, one set left at 22° C., the other at 37° C. At the latter temperature growth was slow, no colour developing in less than a week, and at 22° C. growth was still slower, and there was none earlier than two weeks. Even at the end of this time no colour was present on fish in tubes which contained less than 6 per cent. brine, and here colour was very pale. As the percentages of salt increased, deeper colour developed, so that on 16 per cent. it was rosy red, while on 18 per cent. it was a more vivid red. The effect of temperature seemed to be a difference more of degree than of kind, as tubes containing equal percentages of salt showed a deeper colour when kept at 37° C. than when kept at 22° C.

Fish agar was made up in the proportion of 100 grams salted codfish to a litre of distilled water, 2 per cent. agar, and varying percentages of solar salt. Using this medium, slants were inoculated and three methods of plate culture tried: (1) plates made in the ordinary way by inoculating melted agar, and pouring the plate; (2) by pouring the plate, and, after media had hardened, washing the surface with a suspension of the pink material in salt water; and (3) by making streak cultures on the hardened agar with a platinum needle, charged with the infected parts of the fish. No growth appeared when the plates were made in the ordinary way, nor when the surface was washed with a suspension. Streak cultures on either fish agar slants or fish agar plates were only fairly successful, for no growth developed on agar containing the lower percentages of salt, and, on the higher percentages, when growth did appear, there were no isolated colonies; so that it seemed impossible to get pure cultures.

An observation which suggested the optimum salinity was that the red colour which developed on 16 per cent. salt media most nearly approached the colour found on the fish itself—on 14 per cent. it was a paler pink, while on 18 per cent. it was more red. Consequently, new medium was made up, using ½ lb. shredded salt cod to a litre of distilled water, 2 per cent. agar, and 16 per cent. solar salt. The cod was digested overnight in water, and then cooked in the Arnold steamer for twenty minutes or half an hour. After straining this through a coarse cloth the salt and agar were added to the broth, and the whole heated until salt and agar were thoroughly dissolved, then tubed. At first very little of the cod was removed in straining the broth, but as it made a very dense medium, and was very awkward to get into test tubes, it was thought advisable to use a finer strainer. This medium proved to be entirely successful for the development of colour, and consequently has been used extensively. Possibly a deeper colour developed when less of the codfish was removed in straining, or the deeper colour which seemed to be present may have been due to the density of the medium. However, as the growth was quite as abundant, and the colour a very satisfactory red on the clearer codfish agar, and as mechanical difficulties were overcome by its use, the fine straining seemed the better method.

In order to obtain isolated colonies, plates were poured and allowed to harden. The surface was then stroked with a camel's hair brush charged with a heavy suspension of the red material in 16 per cent. sterile salt solution. The plates were incubated at 37° C. for at least four days before any red colour developed, and sometimes as long as six or eight days. To prevent plates from drying out 15 c.c to 20 c.c.. of the fish agar was used for each plate. It was only to be expected that brush plate No. I would be so covered that there would be no discrete colonies, but the fourth, fifth or sixth plates of each series were more successful. The best one varied to some extent because of the fact that sometimes the suspension was more heavily inoculated than at other times. As a rule, brush plate No. 4 was the first of the series where the colonies were well separated, though not infrequently No. 5 or No. 6 even, was the only one where the colonies were sufficiently isolated to permit transfers from single colonies. On these plates various coloured colonies developed, in addition to the desired red ones, such as sulphur yellow, waxy yellow, luteus, orange, Isabellinus, black, flesh, salmon pink, and two different white ones—one a punctiform colony and the other a small round one. All of these were sub-cultured and will be referred to later, but at present we shall continue to outline the methods adopted to culture the organisms producing red colouration.

From single red colonies transfers were made to sloped fish agar. After four days at 37° C. red growth developed along the line of inoculation—never spreading, except at the lower part of the slant, where the condensation water gathered, and here red was noticed around the edge. Microscopical preparations made from the growth on these agar slants showed what was considered to be the presence of two organisms—a rod and a torula or amoeboid form. Other series of brush plates were made from the agar slants, and again rod and torula-like forms were present. These experiments, which were repeated very frequently from other samples of fish, gave similar results, and as it was thought that two organisms were present, further experiments were started in an attempt to separate the two organisms. 18 per cent. solar salt had been the greatest amount of salt used in making up media for the growth of red organisms, and as it was thought possible that varying percentages of salt might tend to separate the organisms, codfish agar was made up containing varying percentages of salt, 5, 10, 15 and so forth, up to concentration of 35 per cent. On salted codfish agar, to which no solar salt had been added, absolutely no colour developed; on codfish agar containing 5 per cent. solar salt, there was still no colour; on codfish agar containing 10 per cent. solar salt the colour was very faint; on 15 per cent. the colour was distinctly red, and on each succeeding percentage the colour increased in intensity. The amount of growth, from 10 per cent. up, also increased in direct proportion to the increasing amounts of salt. As the agar dried out the salt crystallized at the top of the slant—and even these crystals were coloured red. From this series one may reasonably conclude that the organism or organisms causing red discolouration are halophilic—apparently preferring a saturated solution. Instead of one of the organisms being eliminated it was found that both forms developed on codfish agar containing 35 per cent. salt—that is to say, a saturated solution.

The suggestion that the two organisms might have different thermal death points offered another possible means of obtaining pure cultures. A suspension was made from red growth on an agar slant, in 16 per cent. solar salt solution, and heated in a water bath for ten minutes at 50° C. With a 1 mm. loop drops were placed on the surface of salted codfish agar plates. Other suspensions were made in the same way, one heated for ten minutes at 65° C., a second for ten minutes at 80° C., and the third for ten minutes at 100° C., and plates were inoculated the same as the first one. Growth developed on only the first plate, where the two forms were found together. This same method and procedure was again followed at 50° C., 55° C. and 60° C., but there was no growth at either of the last two temperatures, and again the two forms developed together when heated at 50° C.

Still another attempt was made to secure a pure culture. A fairly heavy suspension was made from the red growth in 16 per cent. solar salt solution, and well shaken. Several successive dilutions were then made until a wet preparation under the microscope contained not more than one form in a field. Using a 1 mm. loop platinum needle, drops were made from this last dilution on salted codfish agar plates. This method, however, proved no more successful than preceding experiments in isolating a single form.

It seemed, therefore, that:

1. These two organisms were impossible to separate, or,

2. That the organisms had considerable mutability of form and, after a long series of experiments, we were inclined to think that this organism is extremely pleomorphic. The reasons for this belief are:

1. Only one type of colony appears on the plates.

2. Isolation of numbers of these on sloped agar or on 16 per cent. codfish broth, containing a piece of filter paper half in and half out of the medium, shows red growth which, on microscopical examination, gives pleomorphic types.

3. By transferring alternately from agar to broth and from broth to agar, and by growing in various salt percentages, we obtained a great many intermediate forms.

4. Further, we think that the organism passes through a symplastic stage similar to that described by Löhnis. Further information on this will be given under the head of "Morphological Characteristics."

4. *Morphological Characteristics.*

The life cycle of the red organism is an interesting one on account of its pleomorphism. It occurs as spheres and also as long rods, the former averaging 2-3 μ in diameter and the latter from 1.0-1.6 μ in width and as long as 15 μ. Between these two extremes many intermediate forms may be found, differing in diameter, length and shape—oval, amoeboid, clavate, cuneate, truncate, pointed, spindle, club, pear shape, irregular, etc. These changes have been noted by observations of hundreds of different examinations from many sources, and in different culture media and over a period of a year.

On discoloured fish the organism is found as a sphere or as a cylindrical rod, varying in size. Temperature at which the fish have been kept and the amount of salt present in or on the tissues seem to be the determining factors, and of these two the latter exerts the greater influence. Higher temperatures and larger salt concentration as a rule increase the size. Whilst this organism, which we propose to call *Pseudomonas salinaria*, is found on cured salted codfish, it originated in all probability from sea water. Six samples of brine of different strengths of concentration have been received from Turks Islands. These range from 10° salinity (sea water) to 100°, the crystallizing point, and from all these, including the sea water, we have isolated and studied the red organism.

Further particulars concerning these results will be found on page 147, but here we wish to emphasize the importance of the gradual increase in salinity, an increase of 30° salinity in about twenty days, and the presence of the vegetable matter which provides the organic nutriment needed by the organism. In the 40° brine we find the organism as a round body, 2-3 μ in diameter, with a clear, double, contoured membrane in unstained preparations, and inside of this slightly granular and pink mass, frequently with a darker spot present. On staining with Giemsa the membrane stains deep violet, the granular content not at all, and the darker spot taking a little colour. Cells of this character are often formed in stronger brine solutions, on fish, and in other culture media.

This spherical form then is the first shape which is encountered in the natural habitat of this organism. As water gradually evaporates and salinity increases the osmotic pressure must increase, but the change being gradual the cell seems able to accommodate itself to these changes, until the point of crystallization is reached when the salt content is about 35 per cent. The organism is now found not only as a sphere but as a cylindrical rod, and if at this stage it is brought into contact with water, it immediately collapses (plasmoptysis) and breaks up into a slimy amorphous mass. With salinity ranging between 15 and 20 per cent. of salt by weight the organism is found as a round, oval or amoeboid form, accompanied by short rods of all shapes. Growth at this stage seems partly by fission, as stretching may be observed with a lighter area, indicating where the membrane is forming, and partly by budding, as figure 8 forms with one half smaller than the other, or attached somewhat to the side and not at the apex of elliptical cells, and occasionally two buds coming from a single cell may be observed. At this stage of growth the cells take the stain (either Giemsa or aniline carbolic Gentian

Violet) lightly but evenly. Occasional rudimentary branching may be noted. Figs. 1, 2 and 3 of Plate III illustrate these various types, which have been observed in saline broths and salt codfish agar up to 16 per cent. to 20 per cent. salt.

Russell and Matzuschita (18) obtained nomad-like forms from typical rod forms of marine bacilli and vice versa, especially in the case of *B. halophilus* of the former author, and *M. flavus* of the latter.

Round forms of slightly larger size than the vegetating forms also occur. Some of these have a darker staining centre, whilst others have a darker staining ring. Both types break up and discharge their contents, the former into a granular symplastic mass, and the ring segments of the latter into granules imbedded in a faintly red tinged cytoplasm (Giemsa).

Whether these round forms should be regarded as microcysts or gonidangia is difficult to state. We have not noted any greater resistance to heat.

Such cells observed in Turks Islands brines resemble the microcysts of *B. ruminatus*, as figured by A. Meyer, and also those of Zukal's *Myxococcus macrosporus*, both as figured by Löhnis (Plate 0, Figs. 61 and 66).

In a number of cases, however, the round cells have very thin walls and the fragmentation of the contents and their subsequent escape lead to the belief that they should be termed gonidangia, and the contents gonidia or reproductive granules.

The transfer of the red organism to media containing higher percentages of salt 25 per cent. to 35 per cent. is followed by a lengthening of the organism, the formation of rods, some straight, others slightly bent, and many odd shaped forms, such are figured on Plate III, 4, 5 and 6. These forms vary in size from 3 μ to 14 μ in length, and individuals of all sizes may be found in preparations, but the general average of length is greater in cultures containing the highest percentages of salt. Branched forms, usually in the form of a T, are frequently present.

On transferring the organism from 25 per cent. to 30 per cent. salt media to 16 per cent. the rods shorten, the nucleoplasm collecting in two or three more or less regular masses which break up into rounded elliptical, clubbed or other shaped, smaller cells. Fig. 9 of Plate IV illustrates this change. Subsequently the cells increase by fission or budding as mentioned already.

Probably Löhnis would consider this change as the formation of gonidia, the round bodies are, however, non-motile.

Symplastic Stage.—The red organism goes through a symplastic stage. The symplasm may be seen in fresh preparations as well as in those stained. Two kinds are noticeable, an amorphous mass, sometimes flaky and sometimes resembling a contoured mass, staining poorly, or slightly. With Giemsa's stain we have noted hyaline masses staining pink; contoured masses, of uneven density, at the periphery thin and toward the centre thicker (Plate IV, Figs. 11 and 13), staining various shades of violet. More frequently the symplastic mass is granular, the granules of varying size staining violet (Giemsa) on a background of cytoplasm of a pink hue (Plate IV, Figs. 12 and 17).

These symplastic masses are formed by the pouring out and melting together of aggregations of cells—the hyaline form probably coming from evenly stained organisms, and the granular modification from cells showing granular staining.

The regeneration of cells seems to follow two different methods. From the hyaline masses we have seen rod-shaped cells forming at the edges and also in the interior, parts of the evenly stained pink cytoplasm splitting off as cells; later a broken line, which stains a deeper colour, appears at various places on the periphery of the rod, subsequently becoming continuous and when this has formed the cell contents stain evenly but a deeper red violet colour, later darker violet granules appear.

From the granular symplasm the granules or regenerative units increase in size, becoming round, amoeboid or other approximately monad shape, or stretch into rods.

The task of obtaining good preparations was one of great difficulty owing to the large amount of salt present in the culture media; the necessity of spreading material in strong salt solutions instead of water, and the effect that such material had on stains, and lastly the poor staining capabilities of the organism.

Diffuse nucleus.—In a number of preparations stained with Giemsa's solution we have been able to note the presence of a diffuse nucleus. This occurred in two forms: One resembling that figured by Bütschli, and consisting of a net work of fibrillar cytoplasm staining pink, with chromatin granules (violet) at intersections. The chromatin granules were around the periphery of the cell and in the median line. The other form observed was somewhat similar, except that in place of the central granules there was an axial filament of chromatin, and the fibrillar net work was absent (Plate IV, Fig. 10, a, b, c). When such cells broke up they gave rise to granular symplasm.

Motility.—The organism is motile when in the form of rods. In the globular form there is marked Brownian movement but no true motility. No movement of the symplasm was observed.

The motility of the cylindrical rods is sluggish, a side to side movement, one end often deeper in the hanging drop than the other. Motile rods have been obtained from both liquid and solid media and from fish.

The flagella are two in number, attached one at each pole. They were most difficult to stain, owing to conditions already mentioned, but although faintly stained the lophotrichous nature of this organism was established.

The mordant used was made from

Tannic acid 20 per cent.—10 parts,
Sat. Sol. Iron Sulphate—8 parts,
Sat. Alc. Sol. Gentian Violet—1 part,

filtered on the slide previously fixed in absolute methyl alcohol. After remaining on the preparation from 5 to 15 minutes, the mordant was washed off with tap water, and then the film was stained by hot aniline carbolic gentian violet (Kütscher) for 2-5 minutes, washed, dried and examined.

Staining Reactions.—The red organism is difficult to stain. Preparations cannot be made in water, as immediately plasmoptysis occurs, forming a viscous mass which can be pulled out several inches. Consequently all preparations must be made in 16 per cent. to 20 per cent. salt solutions. These are allowed to air dry, when the film is covered with a layer of salt crystals. Absolute methyl alcohol is then poured on and allowed to remain for 2-5 minutes, renewing the alcohol from time to time when necessary. Giemsa's solution is then added to the alcohol on the slide and allowed to remain on for 10-30 minutes. The slide is then washed in a beaker of tap water, dried and examined. Instead of Giemsa, anilin carbolic gentian violet may be used. These two stains gave the best results of all those tried. The organism is gram negative.

The usual difficulty of nomenclature arises in placing this organism in any system of bacterial classification.

Buchanan's (32) genus *Pseudomonas* does not fit exactly for red pigment is not mentioned, and organisms producing this colour are included in the next described genus *Serratia*; this genus is described as having peritrichous flagella, the type species being *Serratia marcescens*, Bizio better known as *B. prodigiosus*. The genus *Bacterium* does not apply as the type species is *B. coli* Escherich.

Following the classification suggested by the Committee of the Society of American Bacteriologists, the organism is excluded from the genus *Pseudomonas* for the same reasons as are given above; and the genus *Serratia* is not accepted by the Society (33).

This organism is in many particulars a simple type, having its habitat in all probability in sea water, and being able to grow in salt solutions with the addition of seaweed. It has adapted itself to growing on fish, but cannot use nitrogen in the simpler combinations. In many respects it is unique, consequently the difficulty of classification.

The names Rhodo-bacter and Rhodo-bacillus have been used already for classifying some of the thio bacteria, and hence cannot be used.

If this organism warrants a new genus it might be called Erythrobacter, but for the present it had better be placed in the genus *Pseudomonas.*

As for the specific name Browne has suggested the name *halophilicum* in an unpublished MS. which he kindly placed at our disposal. The summary of his investigation published in the Journal of Bacteriology gives no name; however, his organism is probably similar to ours, but is more thermophilic. Russell (34) has described a bacillus from sea-water under the name *halophilus.* As the habitat of this organism has been traced to tropical salt works the name we suggest is *Salinaria,* belonging to or pertaining to salt works. Some of these works obtaining salt from sea-water were established by the Romans at Ostia and traces of them remain to this day.

The organism, although found on fish prepared in northern climates, has its origin in salts coming from tropical salt works, and hence we prefer as the specific name *salinaria* rather than *halophilicum,* a more general designation and common to many sea-water organisms.

We suggest, therefore, that this red organism be called *Pseudomonas salinaria.*

5. *Cultural Characteristics.*

On beef peptone agar, gelatine, potato, broth, milk, sugar broths, or in fact, on any of the ordinary media, this organism does not grow. Repeated attempts have been made at various temperatures to obtain growth but without results.

Modifications of Culture Media. Media were made with the addition of various percentages of salt. Unless otherwise stated, sea salt was used and definite weights were added to the media. The base of most media was codfish, either obtained fresh, or, when not available, in the form of shredded codfish, or fillets. A certain amount of salt was present in these products, which amount was disregarded when adding different percentages of salt by weight, but which added about two per cent. salt to the finished media. One part of fish was added to two parts distilled water, allowed to digest over night, autoclaved, and then filtered through a cloth. Such filtration gave better results than when a paper filter was used, the amount of fish remaining in the broth encouraging growth.

To the codfish filtrate salt, agar, small percentages of peptone, etc., were added. With high concentrations of salt the amount of agar was increased, and at times considerable difficulty was experienced in getting the agar into solution. Gelatine could not be used at all on account of the action of the salt which prevented solidification. All media were sterilized in the autoclay at 15 pounds pressure for 20-30 minutes.

On codfish agar containing 16 per cent. to 35 per cent. salt growth at 37° C. was slow. In 7 days the amount was moderate, filiform, slightly raised, glistening, smooth, translucent, bright red in colour, odour somewhat unpleasant, consistency viscid, the medium unchanged. Growth at 22° C. was less in amount, but otherwise similar. No growth in agar containing less than 15 per cent. salt.

On 16 per cent. salt peptone agar, without codfish, the growth was very scant after 7 days incubation at 37° C., with the same characteristics as above, but with less colour.

There was no growth on potato slants tubed in brine of various percentages—5, 10, 15, 20, 25, 30 and 35 per cent.

Höye found that *Torula epizoa*, and also a red organism he had isolated, developed well on a special medium made from 30 parts flour, 35 parts salt, and as little water as possible to make a stiff paste. This medium was tried, but, despite massive inoculations, the attempts to culture our red organism were unsuccessful.

Shredded salt cod was used in making two other media: The first one, made from one part fish to three parts cooked potato, and 10 per cent. solar salt with enough milk added to moisten and hold together this paste; the second made from 66 grams of egg white, 100 grams of fish and 10 per cent. solar salt. These two were tubed and sloped, sterilized and then inoculated, but no growth developed on either medium.

Pieces of dried salt cod were cut and tubed in 16 per cent. salt solution in a manner similar to the preparation of potato tubes, sterilized, and then inoculated. After incubation for seven days at 37°C. the growth was red, moderate, spreading, slightly raised, glistening, smooth, and of slimy consistency. At 22° C. growth was slower and less abundant.

Kench cured, hard dried codfish, containing 23.6 per cent. salt and 45.8 per cent. of water, was cut in small pieces, tubed, and without sterilization, inoculated. The tubes were sealed and incubated at 37° C. for 34 days, when growth was slight but distinct. The pieces were then transferred to tubes each containing about three cubic centimetres of a saturated solution of salt, so that the fish came above the liquid. After incubation at 37° C. for thirteen days the red colour had increased in amount in some tubes.

Small pieces of fresh cod were tubed in 16 per cent. salt solution, sterilized and inoculated. Even after four weeks' incubation at 37° C. there was no growth. Presumably the fish was not sufficiently salted.

Cooked finnan haddie was treated in the same way as the above. After incubation at 37° C. for seven days growth was abundant, spreading, slightly raised, glistening, smooth, very bright red colour, disagreeable odour and slimy consistency. In some tubes the red pigment covered the surface of the absorbent cotton, and invariably settled in a mass in the bottom of the tube.

Larger pieces of dried salt cod, fresh cod and finnan haddie were placed in flasks, containing moistened crystals of solar salt, and then inoculated. Abundant growth and bright red colour developed on the dried salt cod and on the finnan haddie at both 37° C. and 22° C., but there was no growth on the fresh cod. In any of the flasks where there was growth the salt crystals became very pink. This suggested another experiment: solar salt crystals in flasks were moistened, sterilized and then inoculated, but there was no growth.

Pieces of dried salt cod were tubed in a solution of 16 per cent. salt and 3 per cent. boracic acid (this acid has been used as a preservative in the U.S.A. fish industry), sterilized and inoculated. No growth developed in these tubes. Evidently boracic acid, in this strength, prevents growth of the red organism.

Beef broth containing 5, 10, 15, 20, 25, 30 and 35 per cent. of salt was tried, but no growth developed in any of this series.

Codfish broth containing 5, 10, 15, 20, 25, 30 and 35 per cent. of salt was made, sterilized and inoculated. In tubes containing 5 and 10 per cent. there was no clouding; on 15 per cent. there was slight clouding; on 20 per cent. more, on 25 per cent. still more, on 30 per cent. somewhat less than in 25 per cent, and on 35 per cent. slightly less than on 30 per cent. The growth was mostly on the surface, small islands of pink growth formed on top of the liquid, and a ring formed after prolonged growth, and a dense sediment, pink in colour, subsequently settled to the bottom.

Because of the marked aerobic character of this organism, tubes of codfish broth were made up similar to the above, with the addition of a strip of filter paper in each tube half in and half out of the liquid. In such tubes a band of red developed on the surface of the paper, its location on the strip depending on the percentage of salt. With low salt content the growth was near the top of the strip, while with higher salt content the growth was nearer the surface of the liquid. This method was found to be simple and was employed extensively for numerous other experiments.

On 16 per cent. salt codfish agar, or on agar with higher percentages of salt, the colonies did not develop unless they were on the surface. When freshly plated from the pink fish the growth was very slow, but after isolation and several transfers on salt codfish agar, the colonies grew somewhat better. In both instances, however, growth was slow. The maximum size, 1.5 mm. in diameter, was reached by the seventh to tenth day at 37° C.; punctiform, smooth surface, raised elevation, entire edge, and internal structure coarsely granular. Colour varied with the variety, medium and age, from a clear pale pink to a transparent cherry red. When growth was picked off with the needle, the colour was distinctly red and transparent.

Fermentation tubes were filled with 16 per cent. salt codfish broth to which was added two per cent. of the various sugars, glucose, lactose, saccharose and glycerine. Good growth occurred in the open arm with clouding and slight reddening. The liquid in the closed arm remained perfectly clear, and no gas or acid was formed.

Temperature Relations.—Temperature experiments were carried out with the red organisms isolated from all samples of fish received, and for verification, repeated many times.

The optimum temperature for growth was about 42° C. Good growth occurred at 37° C., and slow growth at room temperature.

The maximum temperature for growth was 46° C. No growth occurred at 48° C., 50° C., or 52° C.

The minimum temperature for growth was about 10° C. No growth occurred at 7° C.

In connection with these experiments a number of tubes were placed eight inches from a sixty watt tungsten lamp, in one case the temperature being 42° C. and in another case 46° C. There was no growth on the 16 per cent. salt codfish agar slope at either temperature, but both tubes of 16 per cent. salt codfish broth with filter paper half in and half out had abundant growth. As other experiments had shown that 42° C. gave good growth, the results on the agar slope can be explained only by the effect of light and that the fibres of the paper evidently sheltered the organism and permitted growth.

Thermal Death Point, Moist Heat.—The red surface growth on agar slopes was scraped off and put into 16 per cent. salt, making a very heavy suspension, pink in colour and very turbid. Three cubic centimetres of this suspension were pipetted into small bulbs, which were then hermetically sealed. The bulbs were immersed in a large water bath for ten minutes at various temperatures. On removal from the bath, the neck of the bulb was broken with sterile forceps and the contents pipetted out and transferred to sloped 16 per cent. salt codfish agar, to cured fish slants, to fresh codfish slants, and to 16 per cent. codfish broth with filter paper, with the following results:

50° C.	for	10	minutes	—growth	in	13	days	in	all	tubes.
52° C.	"	10	"	— "	"	"	"	"	"	"
55° C.	"	10	"	— "	"	"	"	"	"	"
60° C.	"	10	"	— "	"	8	"	"	"	"
62° C.	"	10	"	— "	"	"	"	"	"	"
65° C.	"	10	"	—no growth in 30 days.						

This experiment was repeated three times with the same results.

Effect of Dry Heat.—Solar salt was inoculated with a suspension of the red organism in 16 per cent. salt solution, and then dried for seventeen hours immediately afterwards. Crystals of this salt were transferred to codfish agar and to codfish broth, containing 16 per cent., 25 per cent. and 35 per cent. salt. The salt was then heated in a drying oven at 97° C., and crystals were transferred to codfish agar and codfish broth, of various salt contents, at the end of ten, twenty, thirty, forty, fifty and sixty minutes. After incubation at 37° C. for eleven days there was no red colour in any of the tubes except those made for control before the salt was heated.

Chromogenesis.—The colour showed best on media containing fish with high percentages of salt. The naturally occurring infection is pink to rose red; the pink on the split surface and the red on the folds of the skin. On salt fish agars and on paper partly immersed in salt fish broth the usual colour is red, the former more translucent. The colours most nearly approach La France pink (Ridgway) and the deeper colours scarlet red to carmine (Ridgway).

The red pigment was soluble in solar salt solution, absolute methyl alcohol, ethyl alcohol, acetone, and slightly soluble in water; insoluble in sodium chloride (C.P.) ether, xylol, chloroform, or weak acetoic acid.

Relation to Oxygen.—The organism is an obligate aerobe. It will not grow in the closed arm of the fermentation tube, or under the surface of agar. We have never seen submerged colonies in agar. A cover glass lowered on the brushed surface of an agar plate is sufficient to prevent growth under it. On salt codfish broths with strips of filter paper, the colour is produced well above the surface of the liquid. On infected fish the organism is always on the surface, and colour is never seen on fish kept well under the brine in puncheons.

Relation to Nitrogen.—16 per cent. solar salt solution was sterilized in tubes. In each tube a strip of filter paper was placed half in and half out of the brine. To these tubes were added various sterilized solutions, so that each tube contained 0.1 per cent. or 0.5 per cent. of the specific solution. All tubes were then heavily inoculated in quadruplicate and incubated at 37° C., for 25 days, with the following results:

16% solar salt—control			No growth.
16% salt (C.P. metal free)—control			No growth.
16% solar salt	+0.1 per cent.	potassium nitrate	No growth.
" " "	+0.5 "	" "	No growth.
" " "	+0.1 "	" "	No growth.
" " "	+0.5 "	" "	No growth.
" " "	+0.1 "	ammonium chloride	No growth.
" " "	+0.5 "	" "	No growth.
" " "	+0.1 "	" tartrate	No growth.
" " "	+0.5 "	" "	No growth.
" " "	+0.1 "	asparagin	No growth.
" " "	+0.5 "	"	No growth.
" " "	+0.1 "	peptone (Difco)	Growth.
" " "	+0.5 "	" "	Growth.

There was more growth on the 0.1 per cent. peptone than on the 0.5 per cent. peptone.

This series shows that this organism is a peptone bacterium.

Hydrogen Ion Concentration.—A series of 16 per cent. salt fish broth tubes were prepared with varying pH; eight tubes of the same pH. In each tube was placed a piece of tested filter paper, acid free, half in and half out of the liquid. All were inoculated and incubated at 37° C. for 21 days with the following results:

pH 4.0—No growth in any of the eight tubes.
pH 4.4—No growth in any of the eight tubes.
pH 4.8—No growth in any of the eight tubes.
pH 5.2—No growth in any of the eight tubes.
pH 5.6—Growth in five out of eight tubes.
pH 6.0—Growth in all tubes.
pH 6.4—Slight growth in all tubes.
pH 6.8—Slight growth in all tubes.
pH 6.8—Slight growth in all tubes.
pH 7.2—Growth in five out of eight tubes.
pH 7.6—Growth in five out of eight tubes.
pH 8.0—Growth in five out of eight tubes.
pH 8.2—Growth in eight tubes.
pH 8.6—Slight growth in eight tubes.
pH 9.0—No growth in any.
pH 9.4—No growth in any.
pH 9.8—No growth in any.

Optimum pH was 6.0. Growth showed in this series in six days, in another series that had growth it did not commence until fourteen days.

Lime Water Series.—In many curing establishments lime water is used as a whitewash. A common practice to remove the red colouration on fish is to rub with lime, and this series was prepared to test the effect of lime on the red organism.

Varying amounts of a clear saturated solution of lime were added to 16 per cent. salt fish broth in the following proportions: 12½, 25, 33, 50 and 75 per cent. lime water. The pH was determined for each lot. All were then inoculated, incubated at 37° C. and examined at various times, up to 32 days.

12½ per cent lime pH 8.0—in eight days all four tubes showed growth.
25 per cent. lime pH 8.6—in eight days all four tubes showed growth.
33 per cent. lime pH 9.0—in eight days one showed growth, in 14 days all four.
50 per cent. lime pH 9.4—no growth in 32 days.
75 per cent. lime pH 9.8—no growth in 32 days.

Lime is difficultly soluble in water, about 0.1 per cent.—and these results seem to indicate that it has some effect when the pH is over 9.4. Evidently this substance has use, as a disinfectant in the form of whitewash, and as a possible means of removing red colour and preventing further red growth on fish, although the labour used in applying it would tend to absorb all profit. As salt codfish is soaked in water before cooking any traces of lime left in the fish would be washed away.

Other Growth Requirements.—We have shown in a preceding series that this organism is a peptone bacterium, and as in the account of the manufacture of solar salt from sea water the red appearance of the evaporating salt water occurs in certain of the reservoirs, an experiment was made in order to find out if the red organism would grow in brine solutions alone, and to see what effect traces of organic substances would have on its development. 16 per cent. solar salt in distilled water was tubed with filter paper strips and sterilized, varying amounts of codfish broth, or agar, were added, with the following results.

1. 16 per cent. salt—no growth in 21 days.
2. 16 per cent. salt+1 drop of fish broth—trace of red growth in one tube.
3. 16 per cent. salt+2 drops of fish broth—slightly more growth than in 2.
4. 16 per cent. salt+3 drops of fish broth—slightly more growth than in 3.
5. 16 per cent. salt+4 drops of fish broth—still more growth.
6. 16 per cent. salt+5 drops of fish broth—abundant growth.
7. 16 per cent. salt+a small strip of agar—no growth in 21 days.

Growth definitely increased in direct ratio with the increasing amounts of fish broth, but it is interesting to note that 1 drop of fish broth gave colour. This was a dilution of 1 to 250.

A number of tubes of 16 per cent. solar salt solution were prepared by adding a small portion of Irish Moss (*Chondrus crispus*) to each tube. Some of these tubes were sterilized, giving jelly-like consistency to the brine. Others were not sterilized. All were inoculated with the red organism, and incubated at 37° C. for thirteen days. In the sterilized tubes growth was moderate but distinct, increasing in amount up to twenty days, while in the unsterilized it was slight.

As in a previous experiment we have shown that solar salt alone will not support growth, and in another experiment—the examination of brines from some of the reservoirs (salinas)—we have shown that the red organism lives and grows in a concentrated brine, in which at one period at least there was an accumulation of seaweed, therefore the above experiment with Irish Moss seems to prove that this material, when added to brine, gives sufficient nutriment or organic matter to support the growth of the red organism.

6. *Viability.*

It was noticed that in old plates in which the media was quite dry and the salt crystallized, a few of the colonies were quite moist and of a clear cherry red colour, consequently these plates and a number of salt fish agar tubes were allowed to dry completely, and later, attempts to recover the organism from these sources were made by transferring the dry scaly material to various culture media with the following results:

From salt fish agar tubes dried, at room temperature, in a well lighted room.	234 days, red growth in 8 days.
	254 days, red growth in 8 days.
	258 days, red growth in 8 days.
	229 days, red growth in 9 days.
	264 days, red growth in 13 days.
	265 days, no growth in 43 days.
	273 days, no growth in 13 days.
	275 days, red growth in two out of three tubes in 13 days.
	289 days, red growth in 14 days.
	307 days, no growth in 13 days.
	308 days, no growth in 13 days.
	324 days, no growth in 13 days.
	332 days, no growth in 13 days.

These experiments show that the red organisms has considerable ability to resist dessication, and remain alive for about nine months. No growth developed on transfers made from plate approximately ten to eleven months old.

This experiment does not confirm the opinion of salt dealers in Turks Islands, that the salt becomes sterile after three to six months' storage, although it must be admitted that the conditions are not by any means similar.

Inoculations on Other Fish than Cod.—Pieces of cured haddock (*Melanogrammus aeglifinus*), cusk (*Brosmius brosme*), pollock (*Pollachius virens*), and hake (*Urophycis chuss*) were inoculated from a culture of the red organism, growing on codfish agar. After incubation at 37° C. for sixteen days there was distinct growth on all these fish, especially on the pollock.

Fresh halibut (*Hippoglossus hippoglossus*) was thoroughly salted and then inoculated from a culture of the red organism. After sixteen days' incubation at 37° C. there was pronounced red colour extending over the entire surface of the fish.

7. *Pathogenicity.*

The organism is not pathogenic. Two rabbits were inoculated subcutaneously, one with a pure culture of the organism, grown on agar and suspended in salt, and the other with a salt suspension obtained by scraping the red surface of infected cod. Neither of these animals showed any ill effects. One of us, rather sensitive to a number of fish proteins, has eaten a considerable quantity of cooked red cod without experiencing any result. Cooked finnan haddie was one day sent to the laboratory, after a considerable amount of it had been served as part of a meal. There was marked red colouration on the finnan haddie. No ill effect followed the eating of this discoloured fish. In this connection the important work of Mauriac may be again cited. His investigations showed that neither human beings nor animals suffered the least trace of poisoning from eating reddened codfish.

8. *Other Organisms Isolated from Reddened Codfish and Able to Grow on High Percentages of Salt.*

A brief description of other organisms isolated from reddened codfish is included in this outline because of their halophilic characteristics and because some of them undoubtedly take part in the subsequent decomposition of the codfish.

An organism, which, growing on 16 per cent. salt fish agar developed as a sulphur yellow colony, was isolated and cultured. Microscopical preparations showed the presence of cocci, slightly more than 1 μ in diameter. They stained well with Loeffler's methylene blue, and were Gram positive. Growth on beef peptone agar, when incubated at 37° C. for two days, was abundant, slightly spreading, raised, glistening, smooth, translucent, bright yellow colour, and possessed no odour. Growth at 22° C. for two days was more abundant, but in other respects the same as at 37° C. In a gelatine stab inoculation the growth was uniform, filiform, but there was no liquefaction. In a beef broth culture, incubated at 37° C. for two days, a pellicle was formed on the surface of the broth, and a flaky precipitate appeared upon shaking the tube. Growth at 22° C. for two days was practically the same. There was no change in either milk or litmus milk inoculated and incubated at 37° C. or at 22° C. for two days—nor even at the end of seven days. On fish agar slopes containing 16 per cent. solar salt, incubated at 37° C. for two days, growth was abundant, filiform, raised, glistening, smooth, translucent, and sulphur yellow colour, not so vivid as on beef peptone agar. When incubated at 22° C. for two days growth was very much the same. On brine agar incubated at 37° C. for two days growth was moderate, filiform, and rather pale yellow colour; and, at 22° C. for the same time, it was practically the same. Colonies on agar plates were punctiform. No gas was produced in lactose, maltose, glucose or saccharose. Fish agar containing varying percentages of solar salt were inoculated and incubated at 37° C. for two days with the following results: on agar containing no salt, 5 per cent. and 10 per cent. salt, growth was abundant; on 15 per cent. it was less, but still fairly abundant; on 20 per cent. it was only moderate; on 25 per cent. and on 30 per cent. it was slight; and on 35 per cent. very slight. There was also a gradual change in colour, from a bright vivid yellow on agar to which no salt had been added, citrinus on 5 per cent. and 10 per cent., sulphureus on 15 per cent. and 20 per cent., to a cream shade on 25 per cent., 30 per cent. and 35 per cent. In many respects this organism resembles *Micrococcus luteus* of Winslow and Winslow, except that in colour ours was more sulphureus than luteus (Saccardo).

When plating out from reddened salt cod many yellow colonies developed on 16 per cent. salt fish agar plates, in three days, at 37° C. They were round in form, about 1.5 mm. in diameter, when full grown, with smooth surface, raised elevation, and entire edge. A microscopical preparation, stained with gentian violet, showed the presence of forms which resembled torulae, rather oval shaped, frequently appearing in twos, side by side. It averaged 2 μ in diameter.

Luteus (Saccardo) coloured colonies also developed on fish agar plates containing 16 per cent. solar salt; and microscopical preparations from such colonies, stained with methylene blue, showed the presence of cocci, slightly more than 1 μ in diameter, which were Gram positive. Growth on beef peptone agar slopes, incubated at 37° C. for two days, was abundant, slightly spreading, raised and glistening, with a definite orange colour. Incubated at 22° C. for two days growth was practically the same. From a gelatine stab inoculation there was infundibuliform liquefaction. In both milk and litmus milk, incubated at 37° C. for two days, there was an orange ring around the top, and a deposit of the same in the bottom, but otherwise there was no change in these media, even at the end of seven days. In beef broth incubated at 37° C. for two days, there was a ring around the top, and considerable clouding through the medium. On fish agar containing 16 per cent. solar salt, and also on brine agar, both incubated at 37° C. for two days, growth was abundant, slightly spreading, raised and glistening. On the former the growth was luteus colour (Saccardo) (20) while on the latter it was more ochraceus (Saccardo). On agar plates colonies were punctiform, mostly under the surface. No gas was produced in glucose, lactose, maltose or saccharose. Fish agar slopes, containing varying percentages of solar salt, were inoculated, and incubated at 37° C. for two days, with the following results: On agar containing no salt, 5 per cent. and 10 per cent., growth was abundant, filiform and luteus colour; on 15 per cent. there was less growth, but still fairly abundant and luteus in colour; on 20 per cent. growth was slight, ochraceus colour; on 25 per cent., 30 per cent. and 35 per cent. growth was very scant, but approached ochraceus in colour. With the exception of colour production the cultural characteristics of this organism approach those of *Micrococcus citreus* of Winslow and Winslow (31).

On some of the fish agar plates Isabellinus colonies developed, which, when transferred, appeared very pale in colour, at first, but in older cultures gradually assumed the darker colour, Isabellinus, which had first attracted attention. Microscopically, this organism was a medium-sized rod, but further knowledge of it is yet to be ascertained. It was found also in Turks Islands brine.

Höye's *Sarcinomyces Islandicus* was isolated from some samples of fish.

A flesh-coloured colony frequently was observed on the salt fish agar plates, which, when examined microscopically, showed the presence of cocci. They stained well with methylene blue, and also were Gram positive. On beef peptone agar sloped cultures, incubated at 37° C. for two days, growth was moderate, filiform, flesh colour. From gelatine stab inoculations growth was filiform, but very scanty with no liquefaction. In beef broth there was slight clouding, flaky precipitate, and no growth at the top. No changes developed in either milk or litmus milk. On a sloped culture of fish agar containing 16 per cent. solar salt, growth was filiform, more abundant than on beef peptone agar, and flesh colour. On brine agar growth resembled that on fish agar, and was again more abundant than on beef peptone agar. There was no gas produced in glucose, lactose, maltose or saccharose. On fish agar containing no salt, growth was beadlike, more appearing near the top of the slope. On 5 per cent. and 10 per cent., growth was abundant; on 15 per cent. it was slightly less than 10 per cent.; on 20 per cent. still less; on 25 per cent., 30 per cent., 35 per cent. there was still growth, but very scant.

These were the most numerous forms occurring, but a number of other organisms appeared from time to time on our plates. Evidently there is a large number of halophilic organisms, and some of them produce deterioration in the cured fish. The metabiotic activities of the organisms here briefly mentioned need to be carefully studied in relation to the disintegration and spoilage of salted codfish, and cannot be dealt with here as it is beyond the scope and purpose of this investigation. Some of the above described organisms were present in Turks Islands brines.

9. *Inspection of Curing Establishments.*

Codfish is obtained both by bank fishing and by shore fishing. The former method necessitates long trips, sometimes several months, so that it is necessary for such fish to be cured on the boat. This is accomplished by what is known as the "kench cure." The fish, after being split, dressed and washed, are stored in the hold of the ship in kench piles of varying length and height, and about four feet wide. Each layer of fish is sprinkled with large amounts of coarse salt. The pressure of the pile and the effect of salt cause the removal of water from the fish. At intervals the kench piles are changed, the lower fish being placed on top. Later, the fish may be dried, or partially dried, on the deck of the ship; or they may be, and frequently are, brought to port to be dried. Instances of such fish being decidedly red when landed have not been unknown.

Shore fishing, on the other hand, is more or less a matter of hours. The fish are landed fresh and cured in either of two ways—in kench piles or in puncheons; the former, identical with that described above, is not employed as frequently as the latter when curing shore fish. Quantitative analyses showed the presence of 31.7 per cent. and 11.1 per cent. sodium chloride in the fleshy part of the kench cured, hard dried codfish. Varying opinions are held as to the frequency of red discolouration in such fish. Certainly it is not free from this infection.

So-called "pickled" fish are cured in tanks or puncheons, usually made from wood (and oftentimes relics of antiquity), though cement lined tanks are frequently observed in the newer establishments. Alternate layers of fish with the split side up and salt are placed in the puncheon, and a brine or pickle forms from the salt extracting the moisture or water from the fresh fish tissues. In this the fish remain until wanted for the market. Quantitative analyses of such fish showed the presence of 45.8 per cent. water and 23.6 per cent. sodium chloride. Very often the top layer of fish, which may be above the surface of the liquid, becomes red, though fishermen claim this reddening is never seen on fish below the surface. This is explained by the extreme aerobic tendencies of the organism concerned.

The amount of infection found throughout the curing houses varied considerably. Where cement is used for floors and tanks it is easily scrubbed and cleaned, and, as there is little absorption, it is naturally free from reddening. But all wood, such as puncheons, tanks, tables, floors, walls, and even wood around the top of cement tanks, is more or less infected. A few firms have tried white-washing all woodwork and wooden utensils, and claim that it is fairly satisfactory; although samples taken from whitewashed articles showed the presence of the red organism, probably the result of re-infection.

Pickle cured codfish is used almost entirely for fillets, boneless and shredded cod. At times consignments of such fish, which appeared in perfect condition when shipped, have been refused at destination because of the development of red discolouration. Or again, the infection may not be detected until after the fish has been prepared for the market. Neither fillets, boneless nor shredded cod are entirely free from infection. One thing is especially noticeable, all the establishments visited which make up this class of goods are using tables which are definitely pink in colour, and splinters taken from such tables showed the presence of the red organism.

There seems to be no attempt to store the fish at a definite temperature during any stage of curing, nor even after it is prepared for the market. It is merely a matter of the temperature prevailing, and varies with the locality and, of course, season of the year. Fishermen claim they have more trouble during the damp and warm seasons than during the clear and cool.

During the months of August and September, 1921, one of us visited a number of fishing stations in New Brunswick and Nova Scotia, examining the varied conditions under which fish is cured and marketed. In all cases, where necessary, samples were taken, and transferred to 16 per cent. salt fish broth, with a strip of filter paper half in and half out of the broth. The cultures thus made were subsequently incubated at 37 per cent. for three to four weeks and the results noted.

The results of these tests are grouped together into *Positive Results*, meaning that red growth appeared on the filter paper visible above the surface of the 16 per cent. salt codfish broth, which, on subsequent examination, proved to be the red organism described here, and *Negative Results*, meaning that no red growth developed in the cultures after four weeks incubation at 37° C.

Positive Results were obtained from:—

1. Scraping from outside of puncheon	North Head, Grand Manan
2. Scraping from outside of puncheon	Whale Cove, Grand Manan
3. Scraping from the outside of a hogshead, not showing red	Digby, Nova Scotia
4. Scraping from the outside of a hogshead, showing red	Digby, Nova Scotia
5. Scraping from inside of puncheon which had been whitewashed	Lunenburg, Nova Scotia
6. Scraping from outside of puncheon	Lunenburg, Nova Scotia
7. Scraping from wooden tank 6 years old never scrubbed or cleaned	Whale Cove, Grand Manan
8. Scraping from outside of cement-lined tank	North Head, Grand Manan
9. Wood from salt bin	Whale Cove, Grand Manan
10. Sliver from salt bin	Yarmouth, Nova Scotia
11. Fish, one year in pickle, one day in sun	North Head, Grand Manan
12. Scraping from fish one year in pickle, no red apparent	North Head, Grand Manan
13. Scraping from fish on top of pickle looking slightly pink	Grand Harbour, Grand Manan
14. Sample of salt lying on top of tank	Seal Cove, Grand Manan
15. Turks Islands salt from split surface of fish in pickle	Grand Harbour, Grand Manan
16. Sample of salt caked on top of fish just out of pickle in butt	St. Andrews, New Brunswick
17. Salt from fish on top of butt, showing trace of red	St. Andrews, New Brunswick
18. Sample of salt from top of pickle in puncheon	Whale Cove, Grand Manan
19. Salt from fish lying out of pickle	North Head, Grand Manan
20. Salt from fish on top of butt, showing trace of red	St. Andrews, New Brunswick

21. Scraping of fish salt crystals from top layer of fish in puncheons, showing red above the surface of the liquid	Lunenburg, Nova Scotia
22. Scraping from top layer of fish*x* in tanks	Yarmouth, Nova Scotia
23. Pickle from top of tank	North Head, Grand Manan
24. Salt, definitely pink in colour, from store	North Head, Grand Manan
25. Turks Islands salt	North Head, Grand Manan
26. Lower part of wall which had been washed and was quite red when sample taken	Digby, Nova Scotia
27. Piece of paper from trimming bench, soaked with salt, and showing red	Yarmouth, Nova Scotia
28. Sliver from sorting and cutting table	Lunenburg, Nova Scotia

Negative Results were obtained from:—

1. Inside cement-lined tank	North Head, Grand Manan
2. Scraping from outside of cement tank	North Head, Grand Manan
3. Splinter from board outside of fish shanty	Whale Cove, Grand Manan
4. Sliver and scraping from bench in baiting room	Whale Cove, Grand Manan
5. Scraping from fish chute where fish are dumped through to be dressed	Whale Cove, Grand Manan
6. Scraping from floor of dressing room	Whale Cove, Grand Manan
7. Scraping from dressing bench.	Whale Cove, Grand Manan
8. Sliver from dressing table	Yarmouth, Nova Scotia
9. Scraping from outside of holder from hopper, after being washed	Whale Cove, Grand Manan
10. Scraping from carrying tank	Whale Cove, Grand Manan
11. Sliver from wharf	Yarmouth, Nova Scotia
12. Sliver from wharf	Digby, Nova Scotia
13. Sliver from floor of curing shed	Canso, Nova Scotia

14. Sliver from floor of salt bin, which appeared quite red	Lunenburg, Nova Scotia
15. Sliver from flakes	Yarmouth, Nova Scotia
16. Sliver from flakes	Lunenburg, Nova Scotia
17. Scraping from whitewashed wall, red showing	Digby, Nova Scotia
18. Scraping from whitewashed wall, high up where no red appeared	Digby, Nova Scotia
19. Cod cured with Liverpool salt	St. Andrews, New Brunswick
20. Piece of cured cod	Whale Cove, Grand Manan
21. Scraping from fresh fish showing red spot—probably blood	Grand Harbour, Grand Manan

These results are in accord with the general biological facts relating to the red organism; briefly, they show red contamination by solar salt, of pickle and fish exposed to air, of wooden tanks and other containers into which brine or solar salt may penetrate, and no red colouration of fish before salt is sprinkled, or in cement-lined tanks, or in places where fish are dressed before salting, or from mined (Liverpool) salt.

10. *Salt the Source of the Red Discolouration.*

The estimated quantity of salt used annually in Eastern Canada in fish curing is 40,000 tons, valued at $480,000. This salt is produced in many places. It may be divided into two classes:

1. *Mined Salt,* coming either from deposits in crystalline form, or from areas underground where sufficient moisture is present to produce a strong brine, which is pumped to the surface and then evaporated. Examples of this kind of salt are known to the trade as *Liverpool* (English salt coming from the Cheshire and Yorkshire mines); *Windsor,* from Ontario; and *Malagash,* from Nova Scotia.

2. *Sea or Solar Salt.* Salt obtained by the evaporation of sea water, coming, as a rule, from countries having a seaboard where the climate is dry and the summer of long duration.

Portugal, Spain, Italy, Austria and the West Indies produce the largest amounts of sea salt, and the brands most commonly used in the Canadian fish trade are known as:

Setubal (Portugal), Cadiz, Torrevieja and Iviza (Spain), Trapani (Italy), Turks Islands (West Indies). This salt is obtained by evaporation of sea water in shallow areas or basins. The method of preparation is as follows:

Sea water at about 10 degrees saline strength is admitted through flood gates, by tide pressure, into the main reservoir, where it remains for from ten to twenty days, according to weather conditions, increasing in salinity from two to four degrees per day in dry weather. During this stage the vegetable matter is deposited in a sort of mossy slime, on the bottom of the reservoir, where it is killed as the brine reaches a strength of 40 to 50 degrees, which occurs after about two weeks standing.

From this main or "weak" reservoir the brine is turned by surface water wheels into smaller divisions, and during the second stage of evaporation, when it increases to a saline strength of 80 to 90 degrees, the lime and other impurities are eliminated. During this process a coating of scale and mud is formed on the bottom of the pans or ponds, the deposit containing a high percentage of lime and other impurities.

When the brine reaches a hundred degrees saline strength, the point at which crystallization begins, it is again turned into other areas or ponds, the bottoms of which are of firm marl carefully scraped and cleaned from time to time, and which, from being constantly worked over and exposed to the sun, are nearly as solid as an asphalt pavement and quite impervious to water. The salt crystals form in cubes on the bottom of these pans and grow into one another, forming a cake of salt varying in thickness from one to six inches, according to the length of time the process continues. When the salt is gathered the surplus brine is drawn off, and the cake broken up and carted out to the points of shipment.

The salt, when first gathered, usually has a decidedly pink cast, but this disappears as the salt is stacked up and exposed to the strong glare of the sun and a hot dry wind. Most of the brine shows a very pink colour during the time the crystallizing is going on, but this disappears from the salt after it is dried out. According to the statement of the manufacturers of solar sea salt, there should be no pink colouration in salt properly cured by three to six months storing after gathering. In other words, time is the principal factor in rendering the salt free from the red organism. It is, however, more remunerative to grind and ship salt within a few days or weeks after coming from the ponds, as loss from rain is avoided, and there is less handling and storing. On account of the large demand from Canada and other countries, much newly made salt is shipped, and in consequence it has been largely infected with the red organism.

It would be advisable to check, by proper laboratory methods, the contention of the salt manufacturers that the red organism will die in salt stored from three to six months under semi-tropical conditions. In any case, it would seem advisable for our importers to insist on being furnished with old salt that has been stored for a period of at least three months.

Chemical Analyses of Salt.—Pure salt should contain only sodium chloride, but all commercial salts contain a certain amount of impurities, sea salt, as a rule, a larger amount than mined salts.

There is a difference of opinion among fishermen as to the best salt for curing fish, but undoubtedly the majority of them favour the use of sea salt, as they consider that fish cured with sea salt are more evenly "struck," and that the fish are more moist and there is no hard crust on the surface of the fish. The mined salts are usually in finer crystals and when used the fish are more quickly "struck," but the salt does not penetrate to the interior so well. It has been suggested that the quick coagulation of the surface protein prevents the penetration of the salt to the interior.

Undoubtedly sea salt is more hygroscopic, and cured fish, if not well dried, will often sweat or become very moist, due to the solar salt taking up water from the atmosphere. Such substances as calcium and magnesium chlorides, are very hygroscopic, and their presence in ground salt produces caking when moisture is present.

Analyses of Mined Salts.

	Worcester, U.S.A.
Moisture	0.2
Calcium chloride	0.19
Magnesium chloride	0.09
Calcium sulphate	0.59
Insoluble constituents	0.01
Sodium chloride	98.94

	Malagash	*Liverpool*
Insoluble	1.954	0.086
Lime	0.220	0.515
Magnesia	0.004	Traces
Sulphuric anhydride	0.320	0.252
Sodium chloride	97.502	98.961

Analyses of Solar Salts.

	Trapani	*Iviza*
Moisture.................	6.45	3.71
Calcium chloride......... ..	.30	.47
Magnesium...............	1.11	....
Magnesium sulphate.......	1.64	.76
Sand or Silica.............	.14	.06
Sodium chloride...........	89.50	94.40

	Turks Islands	*Mediterranean*
Insoluble.............. ...	0.18	0.27
Lime......................	0.72	0.35
Magnesia.................	0.48	0.47
Sulphuric anhydride........	1.20	1.20
Sodium chloride...........	97.42	97.97

Comparison of these two different types shows that the solar salts contain greater quantities of impurities, such as calcium and megnesium chlorides and magnesium sulphates.

We have examined a large number of salts used for curing fish by various methods as follows:—

Method A.—Fresh cod cut in pieces, placed in sterile dishes, sprinkled with various samples of salt, and incubated at 37° C.; the water poured off and more salt added when necessary.

Method B.—Salt sprinkled on codfish agar plates which were moistened when necessary with sterilized codfish broth, or on sloped codfish agar in tubes; both kept at 37° C.

Method C.—Salt sprinkled on sterilized cured codfish in test tubes, incubated at 37° C.

Method D.—Salt placed in sterilized codfish broth, containing a strip of filter paper, half in and half out of the liquid, incubated at 37° C.

The samples of salt tested were secured from dealers, who, as a rule, were able to state where the salt came from; from large fishery companies, from fishery officers and from fishermen who gave no information as to the source of the salt sample.

The results of these tests were as follows:—

	Results from Methods			
Sample	A.	B.	C.	D.
1. Mediterranean from Maritime Fish Co.	Pink	Pink	Pink	Pink
2. Spanish from Gardiner & Doon	Pink	Pink	Pink	Pink
3. Turks Islands from Gardiner & Doon	Pink	Pink	Pink	Pink
4. Sample from Souris (Fishery officer)	Pink	Pink	Pink	Pink
5. Malagash 1	No colour	No colour	No colour	No colour
6. Malagash 2	No colour	No colour	No colour	No colour
7. Liverpool from Halifax dealer	No colour in any			
8. Turks Islands from Halifax dealer	All pink			
9. Torrevieja from Halifax dealer	All pink			
2nd, sample from N.B.		Pink	Pink	
10. Iviza from Halifax dealer	All pink			
11. Guysboro, N.S.		No colour	Pink	Pink
12. John H. Hirtle, Lahave Is., near Lunenburg, N.S.		No colour	Pink	No colour
13. Robert T. Keating Egerton, N.S.		No colour	Pink	No colour
14. D. H. Sutherland Pictou, N.S.		No colour	Pink	Pink
15. Conley Charlotte Co., N.B.		No colour	Pink	No colour
16. F. A. Balson New Brunswick		Pink	Pink	Pink
17. E. C. Qullim Tiverton, N.S.		No colour	Pink	No colour
18. Louis H. Comeau Metighan, N.S.		Pink	Pink	Pink
19. Chas. Q. Diveau Salmon River, N.S.		Pink	Pink	Pink
20. A. G. McLeod Sydney, N.S. (Turks Islands salt)		Pink	Pink	Pink
21. A. G. McLeod Sydney, N.S.		Pink	Pink	Pink
22. Sampson		Pink	Pink	Pink
23. A. J. Murphy		No colour	Pink	Pink
24. P. W. Smith (Turks Islands salt)		Pink	Pink	No colour
25. E. V. Smith Port La Tour, N.S.		Pink	Pink	Pink

26. Wm. Stewart Cape Sable Island, N.S.	Pink	Pink	Pink
27. H. Nelson Newell Cape Sable Island, N.S.	Pink	Pink	Pink
28. P. W. Nickerson, Cape Sable Island, N.S.	No colour	Pink	Pink
29. Sterilized salts.			

The Mediterranean salts and Turks Islands salt were sterilized by boiling in water, allowed to recrystallize and then tested, with the following results:—

	A.	B.	C.	D.
Iviza	No colour in any			
Torrevieja	No colour in any			
Turks Islands A.	No colour in any			
Turks Islands B.	No colour in any			

The results of these experiments show conclusively that all known solar or sea salts, such as Iviza, Trapani, Torrevieja and Turks Islands, contain the red organism which produces the pink discolouration of codfish.

On the other hand, the mined salts, such as Liverpool and Malagash, have never produced the pink discolouration and we have never been able to find any red organism in mined salts.

We have frequently checked these results by microscopical examination and cultural tests, and find the same organism in the solar salt as in the discoloured red fish.

Samples 12, 14 and 17, and from their appearance numbers 21 and 25, were salts that had been used a second time. They still contained the red organism.

Sample 18 was a salt a year in store, yet it contained the red organism.

Sample 13 had been used on other fish than cod—herring, hake, etc. It gave to sterilized fish red colour, but did not grow on the other media.

From the economic standpoint the exclusion of solar salt from the fish trade might cause hardship to the fishermen by increasing prices of mined salts and perhaps curtailing the supply. We suggest as a remedy that the salt dealers equip their establishments with a kiln and run all tropical salt through this machine, thus sterilizing or, at any rate, causing the death of the red organism which has a relatively low thermal death point.

The solar salts dissolved in water, boiled and recrystallized did not contain the red organism.

Experiments with Turks Islands Brines.—Six samples of brine from the various reservoirs belonging to a salt manufacturer in Turks Islands were received one month after the date of shipment.

Several cubic centimetres from each sample of brine were added to 16 per cent. salt codfish agar slopes, to sterilized salt codfish to 16 per cent., 25 per cent. and 35 per cent. salt codfish broth, and all were incubated at 37° C. for three weeks, with the following results:—

1. 10% salinity (sea water)—No red colour.
2. 40% " —No red colour, but organism producing Isabellinus and yellow colours present.
3. 50% " —No red colour, but yellow colour present.
4. 65% " —Red on fish.
5. 80% " —Red colour on all the media.
6. 100-110% salinity (crystallizing point)—Red on fish and broth.

Pieces of fresh cod were suspended in six flasks containing about one hundred cubic centimetres of each percentage of brine, incubated at 37° C. for ten days. Pink colour developed only on the fish in brine of 100-110 per cent. salinity, or crystallizing point. In the flasks containing 10 per cent. salinity, or sea water, the fish was completely digested.

In flasks containing about one hundred cubic centimetres of these brines, a few pieces of Irish Moss (*Chondrus crispus*) were added and gypsum blocks were arranged so that they were half in and half out of the liquid. After incubation at 37° C. for ten days red colour developed in all flasks, including the one containing 10 per cent. salinity or sea water. There was a deep red ring on the gypsum block just above the surface of the liquid, and in some flasks the colour was in specks more or less over the entire surface of the block. Even more marked than the growth on the gypsum block was that on the Irish Moss; it was so pronounced that the moss itself looked distinctly red. On the surface of the liquid a red scum developed. Also the liquid itself became red, and increased in intensity with prolonged incubation.

The Irish Moss used had been in an unopened package for sixteen years, but a control, made by adding pieces of the moss to sterilized salt solutions, gave negative results, the brine remaining quite clear.

Microscopical examinations of the reddened flasks showed the presence of the red organism *Pseudomonas salinaria*.

These experiments prove what already was adumbrated by the experiments with Irish Moss and brine inoculated with the red organism. Seaweed and sea water are sufficient nutriment for vigorous growth of the red organism and in all probability this microbe is a sea water organism, which can adapt itself to growth in strong brine, and resist for a considerable period dessication brought about by evaporation of water under a tropical sun accompanied by warm winds.

On page 142 mention was made of the statement of a salt manufacturer in Turks Islands that in salt stored from three to six months the red colour disappeared. Sterilized bottles were sent and samples of salt were received from this manufacturer in May, 1922, one of which was labelled "*old* crystals, gathered in 1921," and another "*old, old* crystals, gathered in 1919-1920." Crystals from each of these samples were transferred to the following media and incubated at 37° C.:—

A. 16 per cent. salt codfish agar.
B. 16 per cent. brine with filter paper half in and half out of the liquid.
C. Codfish slopes in 16 per cent. brine.
D. Halibut slopes in 16 per cent. brine.
E. Irish moss in 14 per cent. brine, sterilized.
F. Irish moss in 14 per cent. brine, not sterilized.

After five weeks' incubation, at the above temperature, all tubes were distinctly red. These results justify the conclusion that the manufacturer's assertion is not warranted by the experimental evidence, for even the oldest salt proved to be infected with the red organism, which developed well on suitable media at optimum temperature.

Further, this experiment confirms our results on the viability of the red organism, as shown by the long duration of life in old dried out cultures (see page 133), and makes it necessary to take such measures as will destroy the red organism in tropical salts.

11. *Remedial Measures.*

The most important point arising out of these experiments is the fact that tropical or solar salts carry the red organism, and so long as they are used in their present form red colouration of fish is bound to follow.

Curing establishments that use this salt, or have been using it, have their tanks, floors, storage places, puncheons, kench racks, carrying boxes, utensils, etc., impregnated or inoculated with the red organism.

Therefore, all measures taken to deal with this problem must provide for:—

1. A supply of salt free from the red organism.
2. The destruction of the red organism in the curing factories wherever it has infected buildings, utensils, etc.

1. *Recommendations Regarding Salt.*—Mined salt of suitable size of grain should be used until a supply of solar salt free from the red organism can be secured.

Measures should be taken to ascertain the duration of life of the red organism in tropical salt on sale in Canada. Some of the manufacturers claim that such salt stored for three to six months is free from red organisms. This contention has not been corroborated by our laboratory tests.

Importers of solar salt might sterilize this product by kiln heating. A comparatively low, dry heat is necessary—100° C. for thirty minutes.

2. *Recommendations Regarding Cleaning of Curing Establishments.*—All curing establishments which have used solar or tropical salts should clean and disinfect thoroughly all material which has come into contact with salt or fish.

Steam, if available, may be used for this purpose. Puncheons, barrels, etc., should be steamed inside and out, also all utensils, racks, etc.

All parts of the factory that have become infected should be washed well in fresh water. This will have two results: the removal of salt from woodwork, thus preventing the organism from growing, and the fresh water causes the disintegration of the red organism, breaking it down into a slimy mass.

All places infected, and all utensils may be washed in a disinfecting solution of one part sulphurous acid in 50 parts of water.

A good whitewash should be applied as soon as the cleaning up has been effected.

Care should be exercised to keep the premises and utensils clean, all refuse and offal should be frequently removed, and the floors scrubbed and washed often.

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EXPLANATIONS OF PLATES

PLATE I

Fig. 1.—Cured codfish, showing marked red discolouration (the dark areas).

Fig. 2.—Photograph of petri dish containing 16 per cent. salt codfish agar, showing colonies of the red organism and salt crystals (reduced.)

PLATE II

Fig. 1.—Ps. salinaria. From 25 per cent. salt codfish agar, 7 days at 37°.

Fig. 2.—Ps. salinaria. From 16 per cent. salt codfish agar, 7 days at 37° (Antigonish).

PLATE III

Drawings of *Pseudomonas salinaria*, magnified approximately 1000 times.

1.—From a culture in 16 per cent. salt codfish agar, 9 days at 37° (Annapolis).

2.—From a culture in 16 per cent. salt codfish agar, 2 days at 37° (Annapolis).

3.—From a culture in 16 per cemt. salt codfish agar, 2 days at 37° (Annapolis).

4.—From a culture in 25 per cent. salt codfish agar, 9 days at 37° (Annapolis).

5.—From a culture in 35 per cent. salt codfish agar 9 days at 37° (Annapolis).

6.—From a culture in 25 per cent. salt codfish agar, 3 days at 37° (Annapolis). The third transfer in 25 per cent. codfish agar.

PLATE IV

Drawings of *Pseudomonas salinaria.*

1-8.—Round cells of various types. All preparations stained with Giemsa.

1. Dark violet centre, blue margin.
2. Dark violet centre, blue margin.
3. Violet with very dark ring.
4. Ring beginning to break up into granules.
5. Ring completely fragmented into granules.
6. Protoplasm and granules being discharged.
7. Another type with smaller granules, staining pink.
8. An earlier phase of 4.

9.—Above, showing transition from cylindrical to round type. Below, another type.

10.—Types of cells showing diffuse nucleus.

(*a*) Fibrillar protoplasm with chromatic granules at intersections.

(*b*) Axial filament of chromatin, with granules around the periphery.

(*c*) Cell *b* breaking up.

11.—Amorphous symplasm, at times faintly stained or deeply stained (violet), giving appearance of a contoured colony.

12.—Symplasm with granules, some staining more deeply than others, granules round, often in pairs or threes and small rods.

13. Large cylindrical cells forming from symplasm.

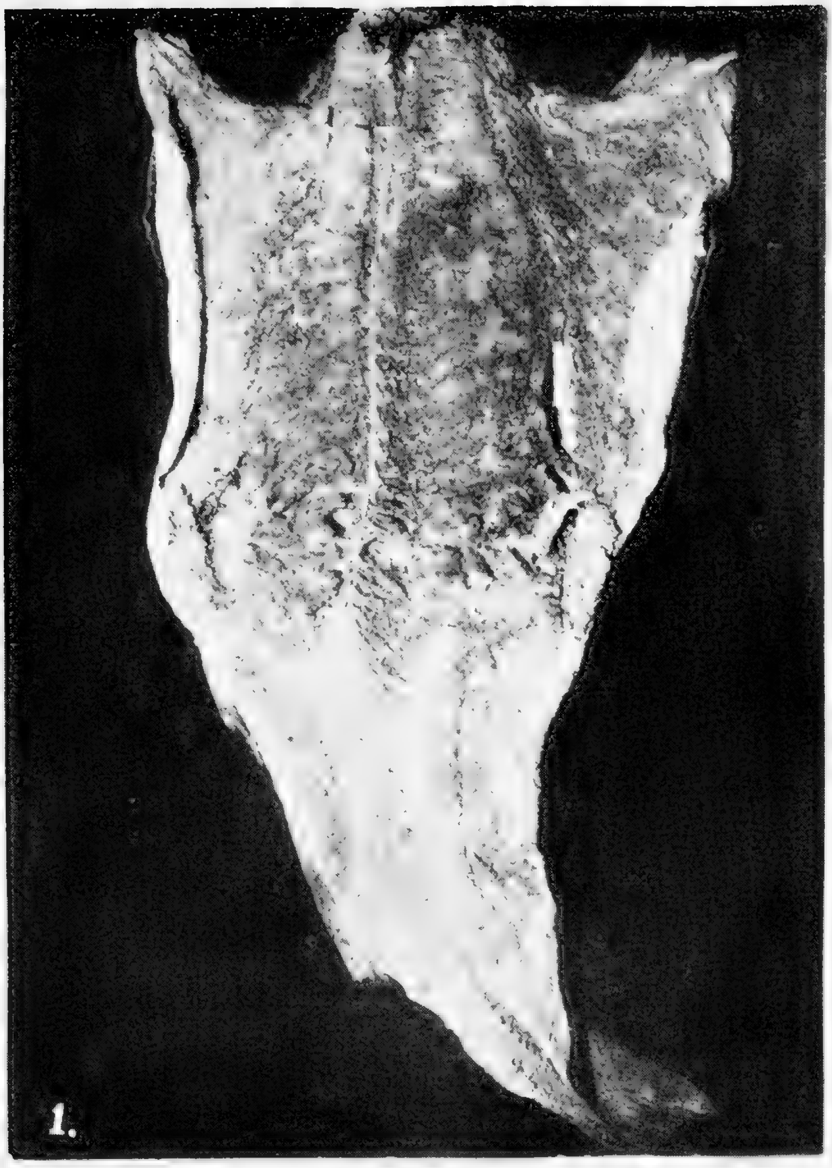
14. Large cells forming a membrane, which shows as a dark broken line at first, later becoming continuous.

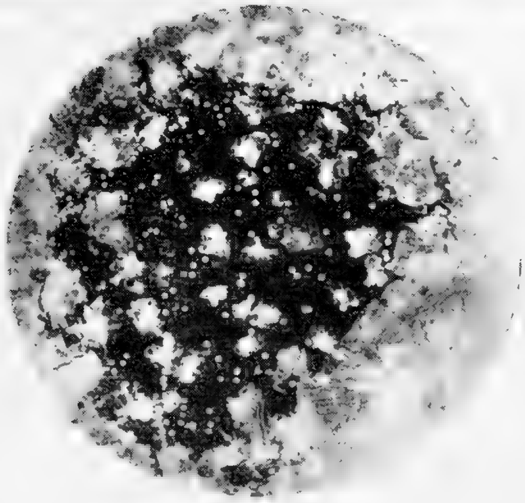
15. Protoplasm stains with Giemsa pale red at first; later stains darker red violet, and is granular.

16. Rods staining faintly pink, with dark violet granules of various sizes.

17.—Cell membrane disappears, and a granular mass results; granules violet on a pink-violet mass.

All preparations stained with Giemsa.

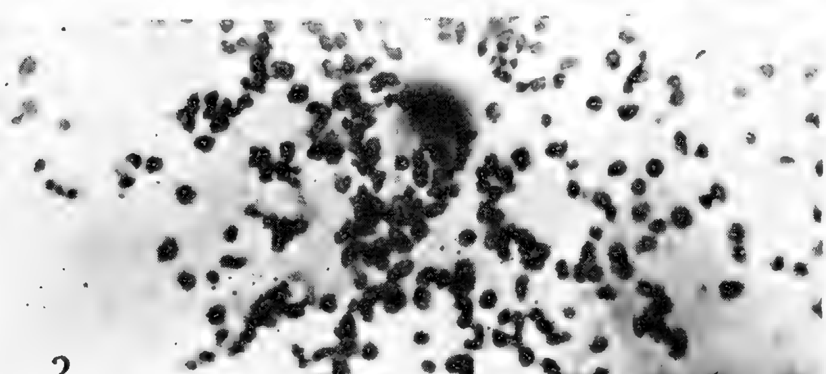




2.

PLATE I

1



2

PLATE II

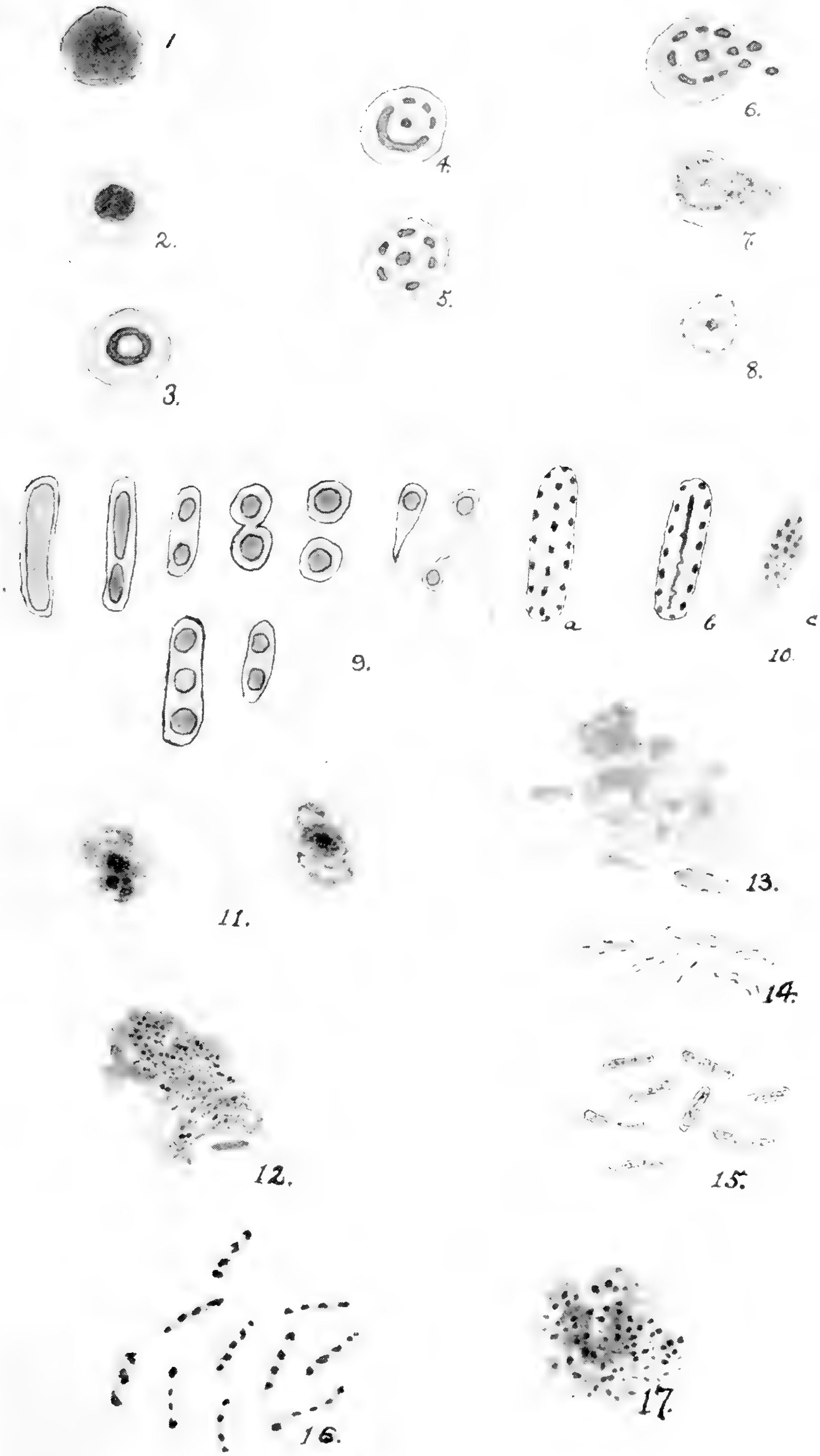


PLATE IV

XVII. *Studies in Wheat Stem Rust* (*Puccinia Graminis Tritici*)

By Margaret Newton, M.A.

Presented by W. P. Thompson, Ph.D., F.R.S.C.

(Read May Meeting, 1922)

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PART I

Biologic Forms of Wheat Stem Rust (Puccinia Graminis Tritici) in Western Canada

Introduction

The control of wheat stem rust, caused by *Puccinia graminis tritici* Erikss, and Henn., is one of the major problems in Canadian agriculture. The problem in Canada is somewhat different from that in the United States because there are not sufficient barberry bushes to account for the great rust epidemics which sweep across the country from time to time. We have, moreover, no evidence to show that urediniospores, after pasing through the long, cold Canadian winter, with the alternate thawing and freezing in the spring, can cause successful infection on the young wheat plants. The generally accepted hypothesis is that the rust moves northward from the United States. If this is true, then the breeding of resistant wheats is the only practical way of solving the problem. That resistant varieties of wheat can be secured has been conclusively shown by Biffen, in England, who succeeded in developing a variety which was not only highly resistant to *Puccinia glumarum* Schm., but which was also commercially desirable. It would seem, then, that the problem is primarily one for the plant breeder. Possible complications and difficulties in the breeding of resistant varieties were indicated by the common experience that a variety resistant in one locality may be susceptible in another. The explanation of this seeming anomaly was made evident by the discovery by Stakman and his co-workers (56 et seq.) that there are several biologic forms of *Puccinia graminis tritici,* and that a variety resistant to one form may be quite susceptible to another.

It is, therefore, quite evident that the plant pathologist must do pioneer work in the analysis of biologic strains of rust before the breeder can be assured of effective results in producing resistant varieties of wheat.

The investigation here reported attempts such an analysis. It was begun at Macdonald College in 1918, and continued at the University of Saskatchewan and the University of Minnesota, until the present time (April, 1922).

Acknowledgments

The work was carried on under the auspices of the Honorary Advisory Council for Scientific and Industrial Research of Canada. Collections were facilitated by an appointment from the Canadian Department of Agriculture in the summer of 1920. The writer wishes to acknowledge the kind help received from Dr. E. C. Stakman and Mr. M. N. Levine, Cereal Investigations, Bureau of Plant Industry, at the University of Minnesota, and Professor W. P. Fraser, Dominion Laboratory of Plant Pathology, at the University of Saskatchewan.

Historical Summary

The phenomenon of biologic specialization in rusts has for many years attracted the attention of workers in pure and applied biology because of the light which it throws on the parasitic behaviour of fungi, and lately because of the practical application which may be made by the establishment of a basis for rust resistance.

Eriksson (15) was the first to show definitely that biologic specialization occurs in cereal rusts. He worked with *Puccinia graminis* Pers. and in 1894 showed that what was usually considered as one species attacking all the common cereals in reality consisted of several pathological strains or biologic races.

This discovery stimulated much research, and various biologists in Europe and the United States began work in earnest upon this problem. The whole field of biologic specialization has been carefully reviewed by Reed (49), and specialization in the cereal rusts by Stakman (52) and a detailed review, therefore, is not given here. Only those papers are reviewed which are directly relevant to the present problem.

Until 1916 the existence of biologic forms of *P. graminis* on wheat was not suspected. During that year a form of stem rust was collected by Stakman and Piemeisel (58) in the Palouse district of Washington and Idaho to which certain varieties of wheat were almost immune, although these same varieties were readily susceptible to a form of rust collected at St. Paul, Minnesota. This susceptibility and immunity of the same variety of wheat in different localities was most readily explained by assuming the existence of more than one biologic form of the rust fungus, each form capable of affecting only certain wheats.

Since 1916, by far the most extensive work on biologic specialization of *P. graminis* has been done by Stakman and his co-workers (36, 37, 54, 55, 56, 57, 58, 59, 60) at the University of Minnesota, in cooperation with the United States Department of Agriculture. These investigators demonstrated conclusively the existence of about a dozen biologic forms, which differ from one another chiefly in their infection reactions towards wheat varieties. Experiments were conducted with about twenty-five strains and varieties of wheat, including representatives of *Triticum aestivum*, *T. durum*, *T. compactum*, and *T. monococcum*. All degrees of resistance and susceptibility to the biologic forms then known were met with, from complete resistance in Khapli (C.I. 4013) an emmer, to complete susceptibility in the club wheats. The remainder of the varieties fell into an intermediate group, susceptible in varying degrees to some forms of the rust, and resistant or immune to others.

To test the question of the possible temporary character or mutability of these forms, Leach (36) and Stakman and Levine (60) studied the behaviour of one of them, *Puccinia graminis tritici compacti*, and found it to be as constant parasitically as the forms originally described by Eriksson (15).

Recently Mains and Jackson (39) have shown that *Puccinia triticina* Erik. consists of at least two biologic forms.

In 1919, Hoerner (31) found evidence of the existence within oat varieties of at least four specialized races in *Puccinia coronata* Cda., which next to *Puccinia graminis* is probably the most extensively investigated rust from the standpoint of heteroecism and biologic specialization.

Various workers have reported biologic specialization in the sunflower rust, *Puccinia helianthi* Schw., but results have not been conclusive until 1922, when Bailey (3) was able to demonstrate definitely three distinct types of infection on *Helianthus annuus*, supplying final proof of the existence of biologic forms of this fungus.

Thus it is seen that a large number of rust species have been investigated from the standpoint of specialization to particular hosts, and the phenomenon has been found to be of wide occurrence.

Importance of the Present Investigation

The black stem rust is the greatest source of loss to the wheat-growing industry in Western Canada. So serious is the condition that wheat-growing is no longer profitable in large areas of the Red River Valley, and large numbers of farmers are threatening to abandon their farms unless a solution of the problem is forthcoming. Taking Canada as a whole, the losses in a normal year amount to from 5 per cent. to 10 per cent. of the wheat crop. This represents a loss of about eight million bushels in the prairie provinces alone, a loss which in epidemic years may be increased to seventy-five or one hundred million bushels.

Every wheat grower realizes his great annual loss, but he is powerless to prevent it. The weapons of the fruit grower, spraying and dusting, cannot be employed, not only on accouut of their prohibitive cost, but also because of the mechanical injury spraying machinery would cause to the maturing wheat crop, as rust does not appear on the plants until the heads are well advanced.

The farmers' only hope lies, then, in the production of rust-resistant varieties of wheat. Not only would such wheats largely eliminate one of the most important causes of unfavourable fluctuation in yield, thus greatly increasing the financial returns, but they would also contribute in an important degree to the safety and stability of the wheat-growing industry.

The problem is, however, complicated by the discovery of the occurrence of more than one biologic form of stem rust. This discovery was not only of scientific interest but had a direct bearing on the breeding of grain for rust resistance. It showed why "few varieties seem to be universally resistant" (Freeman and Johnson, 24), and explained the diverse opinions of workers in different localities as to the relative rust resistance of certain wheat varieties.

A study of biologic forms must precede the breeding of rust-resistant wheats. As Stakman has pointed out, "methods of breeding for rust resistance must be changed fundamentally. The breeder must know and work with those forms of rust which occur in the region for which his new variety is intended, and even then breeding must be very largely a regional or even a local problem."

With the numerous forms of stem rust on wheat present in the United States, the question naturally arose, "Did biologic forms of stem rust occur in Canada?" Until the present investigation was undertaken, no specific work had been done along these lines, although observations made by Dr. W. P. Thompson of Saskatchewan

University, in his breeding experiments, had suggested very strongly that such strains did exist.

The task of the Canadian plant pathologist, then, is to gain a definite knowledge of the number, characteristics, and geographical distribution of the biologic forms in Canada. It was with this end in view that this investigation was undertaken. Three years' results are now available and are presented in the following pages. It is hoped that they may be of immediate practical assistance to plant breeders.

Experimental Materials and Methods

Collections of rust were made in the field from the time the first pustules appeared in early summer until late in September. It was thought that if the observation were correct, that rust moves northward in waves across the continent, then possibly different biologic forms of rust might appear at different periods of the summer.

Material was collected in 81 representative localities of Manitoba, Saskatchewan and Alberta.

All the preliminary work of differentiating the numerous rust collections into distinct forms was carried out in the greenhouse, where conditions could be more definitely controlled than in the field.

Differential Hosts

The identification of the biologic forms necessarily involved the use of many varieties of wheat as differential hosts. Preliminary experiments with a number of different groups of wheat varieties indicated that the series used for this purpose by Stakman and his co-workers at the University of Minnesota were by far the most satisfactory. The list which this series comprises is given in Table I. The name of the variety is preceded in each case by the abbreviation used in the key and in the tables presented later.

Table I.—List of differential hosts used in identifying biologic forms.

Triticum aestivum

- KRd—Kanred, C. I. 5146 (Kans. 2401).
- Ko—Kota, C. I. 5878.
- Ma—Marquis, C. I. 3641 (Minn. 1239).

Triticum compactum

- Lc—Little Club, C. I. 4066.

Triticum dicoccum

- Em—Emmer, C. I. 3686 (Minn. 1165).
- Kpl—Khapli, C. I. 4013.

Triticum durum
Ac—Acme, C. I. 5284 (S.D. 284).
Arn—Arnautka, C. I. 4072 (S.D. 150).
Mnd—Mindum, C. I. 5296 (Minn. 470).
Spm—Speltz Marz, C. I. (Minn. 337).
Triticum monococcum
Enk—Einkorn, C. I. 2433.
C. I. = U.S. Dept. Agr. Cereal Investigation Office number.

Table II.—Explanation of symbols used to indicate types and degrees of infection of wheat varieties by *Puccinia graminis*.

0. Immune.
No uredinia developed; hypersensitive (sharply chlorotic) flecks sometimes present.
1. Very Resistant.
Uredinia minute and isolated; surrounded by sharp, continuous, hypersensitive areas.
2. Moderately Resistant.
Uredinia isolated and small to medium in size; hypersensitive areas present; pustules often surrounded by green islands.
3. Moderately Susceptible.
Uredinia medium in size; coalescence infrequent; development of rust somewhat subnormal; true hypersensitiveness absent; chlorotic areas, however, may be present.
4. Very Susceptible.
Uredinia large, numerous and confluent; hypersensitiveness entirely absent.

Miscellaneous Symbols.
(;) Chlorotic flecks.
(x) Mixture of strains.

Any particular collection usually comprised a mixture of forms which first had to be separated by cultural experiments. Each form was then cultured separately upon all the differential hosts, and this operation was repeated until constant results were obtained. The reactions towards all of the wheats were then compared with the reactions of the forms described by Stakman and Levine. In all cases they were found to coincide with the reactions of one or other of the forms described by these authors, and consequently the same strain numbers were adopted.

The methods of inoculating and culturing the rusts were similar to those described by Stakman and Piemeisel (59). In recording the

ANALYTICAL KEY TO BIOLOGIC FORMS OF PUCCINIA GRAMINIS TRITICI

- Ma - R
  - Krd - R
    - Ko - R
      - Arn - R
        - Kub - R 11
        - Kub - S
          - Enk - R XXV11
          - Enk - S XX111
      - Arn - S
        - Mnd - R V1
        - Mnd - S
          - Kub - R 1V
          - Kub - S
            - Enk - R XV1
            - Enk - S X1V
    - Ko - S
      - Mnd - R XXV111
      - Mnd - S X1X
  - Krd - S
    - Arn- R V11
    - Arn- S X
- Ma - S
  - Krd - R
    - Ko - R XX1V
    - Ko - S.
      - Arn - R 1
      - Arn - X
        - Em - R XX1X
        - Em - S XXX
      - Arn - S
        - Mnd - R XXV1
        - Mnd - S
          - Kub - R
            - Em - R V
            - Em - S V111
          - Kub - S
            - Enk - R XX1
            - Enk - S
              - Em - R XV11
              - Em - S 1X
  - Krd - S
    - Ko - R XXX1
    - Ko - S
      - Arn - R
        - Mnd - R
          - Kub - R 111
          - Kub - S
            - Ao - R XX
            - Ao - S XV111
        - Mnd - S
          - SpM - R XXV
          - SpM - S XX11
      - Arn - X XXX11
      - Arn - S
        - Mnd - R X11
        - Mnd - S
          - Kub - R X111
          - Kub - S
            - Em -R X1
            - Em -S XV

type and degree of infection the symbols adopted by Stakman and Levine in their work on biologic specialization were used. A detailed explanation of the meaning of these is given in Table II. Briefly stated, 0, 1 and 2 designate varying degrees of resistance, collectively referred to by the symbol R in the "Key to Biologic Forms" given above. On the other hand, 3 and 4 designate degrees of susceptibility, referred to in the key by the symbol S. Experience has shown that the degree of resistance or susceptibility of a given wheat variety to a given biologic form, under greenhouse conditions, is remarkably constant. In the field, however, there is a tendency towards a somewhat lighter degree of infection. In some cases, a variety that would ordinarily score 3 in the greenhouse may score 2 in the field. Varieties are given the score representing the degree of infection to which they most nearly approximate, this figure being followed, where necessary, by *plus* or *minus* signs to indicate deviations from the standard.

The procedure just outlined for identification of the forms was facilitated by the use of the accompanying key devised by Stakman and Levine. This key is constructed upon the same principle as an ordinary botanical key. The compound symbols employed consist of the abbreviated designations for the differential hosts, followed by R or S, denoting resistant and susceptible, respectively. The use of the key will be illustrated by the following example: A form collected on Kanred at Saskatoon, Saskatchewan, on September 14, 1920, was cultured on the hosts given in Table I. Marquis proved susceptible. This threw the form in question into the second main section of the key, viz., Ma—S. The test on Kanred showed this variety also to be susceptible. This led us to section KRd—S of the key. Kota also proved susceptible. This placed the form in Ko—S. As Arnautka and Mindum were both resistant, we arrived at Mnd—R. Kubanka, on the other hand, was susceptible, thus bringing up to Kub—S. But one variety, Acme, remained to be examined. Since this proved susceptible the form was identified as number XVIII.

Results

Fourteen biologic forms have been demonstrated, by the methods described, to be present in Canada. These forms have proved to be identical with some of those described by Stakman in the United States. In the latter country, however, a considerable number of additional forms have been demonstrated.[1] The date and place of collection, host on which collected, and complete infectional characterization of the Canadian forms are summarized in Table III.

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[1]Unpublished data from E. C. Stakman.

TABLE III

DISTRIBUTION IN CANADA OF THE BIOLOGIC FORMS OF *Puccinia graminis tritici* WITH A RECORD OF THEIR INFECTION CAPABILITIES

Form	Place of collection of rust	Date	Host on which collected	Character of infection on differential hosts											
				Lc	Ma	KRd	Ko	Arn	Mnd	Spm	Kub	Ac	Enk	Em	Kpl
I	Brandon, Man. Carnoustie, Sask. Morris, Man.	Sept., 1919 Sept., 1919 Aug, 23, 1920	Marquis Marquis Marquis	4	4	0	3+	0;	1=	1−	3±	3	3	0;	1.
III	Brandon, Man. Morden, Man. Rosthern, Sask. Watrous, Sask.	July 27, 1920 " " Sept. 2, 1920 Sept. 13, 1920	Marquis Ruby Minister Marquis	4	3++	3++	3+	1=	0	1−	1	3	3	1	0;
IX	Brandon, Man. Carlyle, Sask. Edmonton, Alta. Leslie, Sask. Rosthern, Sask. Saskatoon, Sask. Winnipeg, Man.	Aug. 28, 1920 Sept. 22, 1920 Sept. 8, 1920 Sept., 1919 Sept. 2, 1920 Sept. 25, 1920 Aug. 25, 1920	Emmer Marquis Emmer Marquis Minister Marquis Emmer	4	3	0	3±	3=	3++	3+	3++	3−	3+	3±	0.
XI	Brandon, Man. Edmonton, Alta. Moose Jaw, Sask.	Sept., 1919 Sept., 1919 Aug. 5, 1920	Marquis Marquis Marquis	4	3++	3++	3+	4	4	4	4	3+	3	0;	1−
XII	Indian Head, Sask. Moose Jaw, Sask.	Aug. 30, 1920 Aug. 5, 1920	Marquis Marquis	4	4	3	4−	3	1	1	1+	4−	3+	1	1
XV	Melfort, Sask.	Sept., 1919	Marquis	4	4	4	4=	4	4−	4−	4−	4=	3±	4−	1=

XVII	Alameda, Sask.	Sept. 28, 1921	Marquis												
	Camrose, Alta.	Sept. 10, 1920	Marquis	4	4	0	4=	4±	4	4−	4	3	3+	0;	1=
	Carleton, Sask.	Sept., 1919	Marquis												
	Dauphin, Man.	Sept. 1, 1920	Marquis												
	Edmonton, Alta.	Sept. 8, 1920	Emmer												
	Govan, Sask.	Sept. 15, 1920	Marquis												
	Howell, Sask.	Sept., 1919	Marquis												
	Indian Head, Sask.	July 14, 1920	Ruby												
	" " "	July 19, 1920	Ruby												
	Morris, Man.	July 23, 1920	Marquis												
	Napinka, Man.	Sept. 24, 1920	Marquis												
	Prince Albert, Sask.	Sept., 1919	Marquis												
	Rapid City, Man.	July 16, 1920	Marquis												
	Red Berry Lake, Sask.	Sept., 1919	Marquis												
	Rosthern, Sask.	Sept. 2, 1920	Minister												
	Saltcoats, Sask.	Sept., 1919	Marquis												
	Saskatoon, Sask.	Aug. 2, 1920	Ruby												
	"	Sept., 1919	Marquis												
	Shellbrook, Sask.	Aug. 16, 1920	Marquis												
	Stettler, Atla.	Sept. 9, 1920	Marquis												
	"	"	Hordeum jubatum												
	Vermilion, Alta.	Sept., 1919	Marquis												
	Winnipeg, Man.	July 5, 1920	Ruby												
	"	July 17, 1921	Marquis												
	Yorkton, Sask.	July 15, 1921	Marquis												
	Zealandia, Sask.	Sept., 1919	Marquis												
XVIII	Melfort, Sask.	Sept., 1919	Marquis	4	4	3+	3−	0;	0;	2=	3	3	3	0;	0;
	Riverstone, Sask.	Sept., 1919	Marquis												
	Saskatoon, Sask.	Sept. 1, 1920	Kanred												
	Vermilion, Alta.	Sept. 11, 1920	Marquis												
	Weyburn, Sask.	July 9, 1920	Marquis												
	Yorkton, Sask.	July 15, 1920	Marquis												

Form	Place of collection of rust	Date	Host on which collected	Character of infection on differential hosts											
				Lc	Ma	KRd	Ko	Arn	Mnd	SpM	Kub	Ac	Enk	Em	Kpl
XIX	Indian Head, Sask.	Sept., 1919	Marquis	4	1++	0	3=	4−	3+	3+	4±	4−	4−	0	1.
XXI	Alameda, Sask.	Sept. 18, 1921	Marquis												
	Carleton, Sask.	Sept., 1919	Marquis	4	4	0;	3++	4	3++	3+	3+	3	1=	0	0.
	Winnipeg, Man.	Sept., 1919	Marquis												
XXIV	Carnoustie, Sask.	Sept., 1919	Marquis	4	3+	0;	1±	3++	4	4	4	4	3	0;	0.
	Saskatoon, Sask.	July 17, 1921	Marquis												
XXIX	Brandon, Man.	July 27, 1920	Marquis	4	4	0	3+	x	x	x	x	3±	3+	0;	1.
	"	Sept. 27, 1920	Marquis												
	Carlyle, Sask.	Sept. 9, 1920	Marquis												
	Edmonton, Alta.	Aug. 12, 1920	Club												
	Elbow, Sask.	Sept. 10, 1920	Marquis												
	Indian Head, Sask.	Aug. 30, 1920	Kota												
	Lacombe, Alta.	Sept. 9, 1920	Barley												
	Macleod, Alta.	Sept. 22, 1920	Marquis												
	Mervin, Sask.	Sept. 9, 1920	Marquis												
	Moose Jaw, Sask.	Sept. 20, 1920	Marquis												
	Morden, Man.	Aug. 4, 1921	Marquis												
	Prince Albert, Sask.	Aug, 2, 1920	Marquis												
	Quill Lake, Sask.	Sept., 1919	Marquis												
	Rosetown, Sask.	Sept. 12, 1920	Marquis												
	Rosthern, Sask.	Sept. 2, 1920	Pentad												
	Treesbank, Man.	Aug. 3, 1920	Marquis												
	Vegreville, Man.	Sept. 11, 1920	Hordeum jubatum												

	Vegreville, Man.	Sept. 9, 1920	Marquis													
	Weyburn, Sask.	Sept. 21, 1920	Marquis													
XXX	Carlyle, Sask.	Sept. 22, 1920	Marquis	4	4+	0;	3+	x	x	x		x	3	3±	4−	0;
XXXII	Morden, Man.	July 27, 1920	Ruby	4+	3+	4	3	x	x	x		x	3	3	1=	1−
	Rosthern, Sask.	Sept. 2, 1920	Barley													
	Treesbank, Man.	Aug. 3, 1920	Ruby													
	Vermilion, Alta.	Sept. 11, 1920	Marquis													
	Winnipeg, Man.	July 17, 1921	Marquis													

Identity and Nature of the Forms Isolated

The identity and nature of the forms isolated can be seen from Table III, which includes a summary of the infection reactions of each form on all the differential hosts. In order to illustrate the use of this tabular summary, the data for two forms have been abstracted from the table, and are given below, together with a summarized description in words corresponding to the symbols used in the table.

Character of infection on differential hosts

Form	Lc	Ma	KRd	Ko	Arn	Mnd	SpM	Kub	Ac	Enk	Em	Kpl
I	4	4	0	3+	0;	1−	1−	3±	3	3	0;	1
XV	4	4	4	4=	4	4−	4−	4−	4=	3−	4−	1=

Little Club	I	Heavy normal infection.
	XV	Heavy normal infection.
Marquis	I	Heavy normal infection.
	XV	Heavy normal infection.
Kanred	I	Absolute immunity.
	XV	Heavy normal infection.
Kota	I	Moderate susceptibility.
	XV	Moderate susceptibility.
Arnaütka	I	Absolute immunity, chlorotic flecks.
	XV	Heavy normal infection.
Mindum	I	Decided resistance.
	XV	Heavy infection.
Speltz Marz	I	Decided resistance
	XV	Heavy infection.
Kubanka	I	Moderate susceptibility.
	XV	Heavy infection.
Acme	I	Moderate susceptibility.
	XV	Moderate susceptibility.
Einkorn	I	Moderate susceptibility.
	XV	Moderate susceptibility.
Emmer	I	Absolute immunity, chlorotic flecks.
	XV	Heavy infection.
Khapli	I	Very high resistance.
	XV	Decided resistance.

As will be seen in Table III, most of the forms were isolated and identified several times from material of different collections. Since the procedure was in principle the same in all cases it will be sufficient to present here the records of one typical series of inoculations for each form. These are given in Diagrams 1 to 14. An explanation of the symbols used will be found under Diagram 1.

In Diagrams 3, 4, 5, 7, 9, 10, 11, and 12, it will be seen that the rust collections in question proved to be composed of but one form. It should be pointed out, however, that these cases have been deliberately selected to simplify the presentation of these illustrative data; the circumstance of a collection consisting of only one form was unusual. The average condition is better represented in Diagrams 1, 6, 8, 13, and 14, where the collections consisted of 2 forms. Occasionally a collection yielded 3 forms, as in the case shown in Diagram 2.

It will be seen in the latter group of diagrams that the transference of the rust of a given collection to the test wheats frequently resulted in the appearance of 2 forms of pustules, small and large, a "1-4" infection. It was then assumed that a mixture of forms was present, resistance of the host to one form being represented by "1" and susceptibility to the other form by "4." The next step was to separate the forms. Accordingly spores from the small and large pustules were transferred separately to different plants of the same host variety. If practically all the pustules resulting from this inoculation were small in the case of the one host plant, and large in the case of the other, the presence of at least 2 forms in the original rust collection was practically confirmed. These results were always checked by further inoculations on all the differential hosts given in the key, a procedure which, as previously noted, served also for the final identification of the forms.

The reactions of Forms XXIX, XXX and XXXII are still imperfectly understood. They always give two degrees of infection, "1-4," on the Arnautka, Mindum, Speltz Marz and Kubanka varieties of durum wheat; whereas, on all the remaining differential hosts they behave normally as pure forms. For two years every effort has been made to separate these apparent mixtures, but in vain. Cultures made from a single spore of each form still failed to resolve the components.[2] It has been suggested that these forms must be heterozygous, or perhaps homozygous with a genetic composition resulting in this type of infection. It seems to the writer at least equally possible that the aberrant behaviour is connected with the physiological relationship of the fungus and the host, perhaps even arising from the genetic composition of the host itself with regard to rust resistance. However, the problem must await further investigation, and perhaps the development of more refined technique, before it can be explained.

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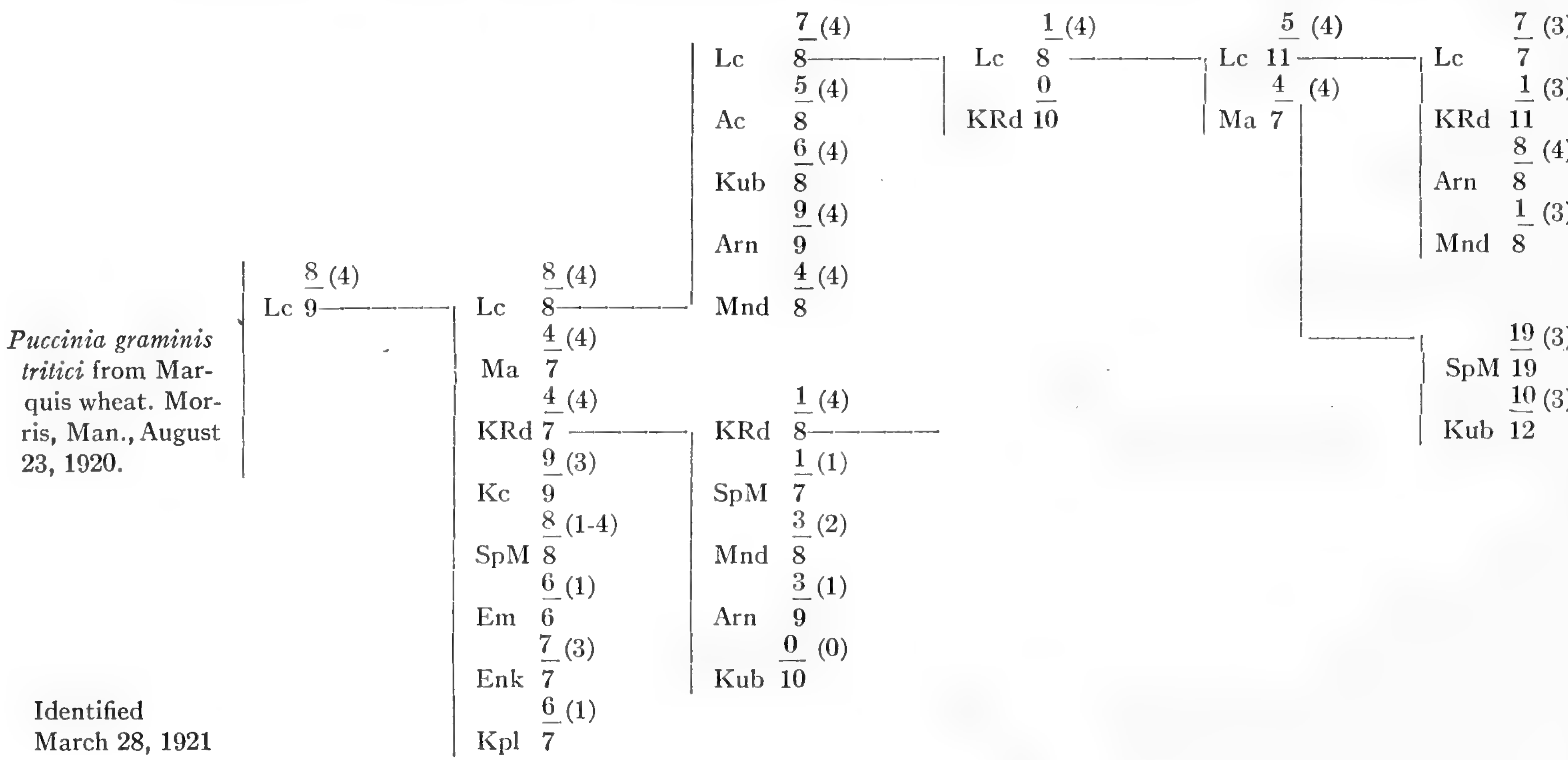
[2]Unpublished data from E. C. Stakman.

DIAGRAM I—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORMS I AND XVII



Explanatory Note:—The fractions following the abbreviations of varietal names indicate the number of leaves inoculated (denominator) and the number developing consequent uredinia (numerator). The figures in brackets indicate the degree of infection. (Cf. Table II).

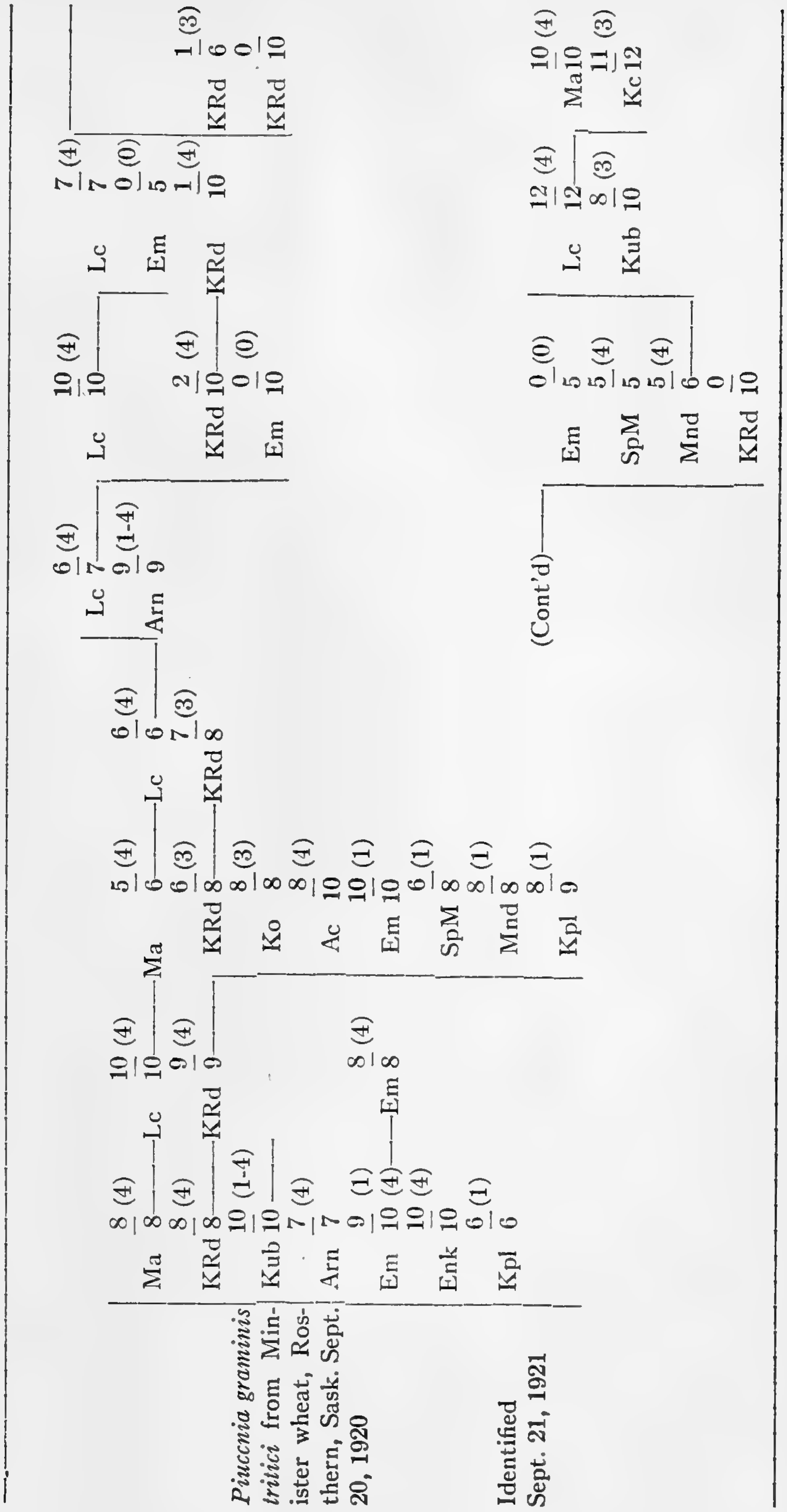


DIAGRAM 2.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORMS III, IX AND XVII

DIAGRAM 3.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORM IX

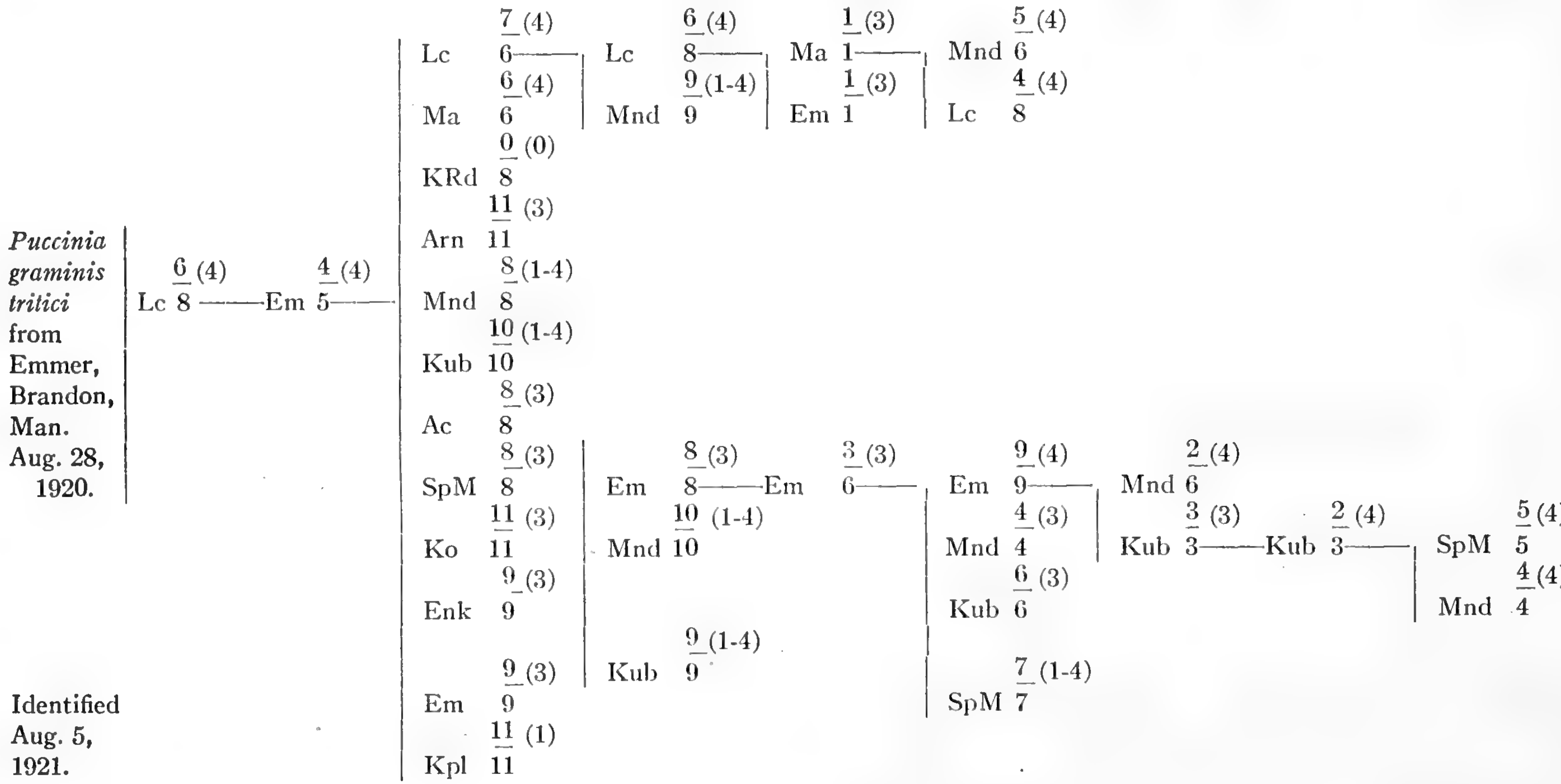
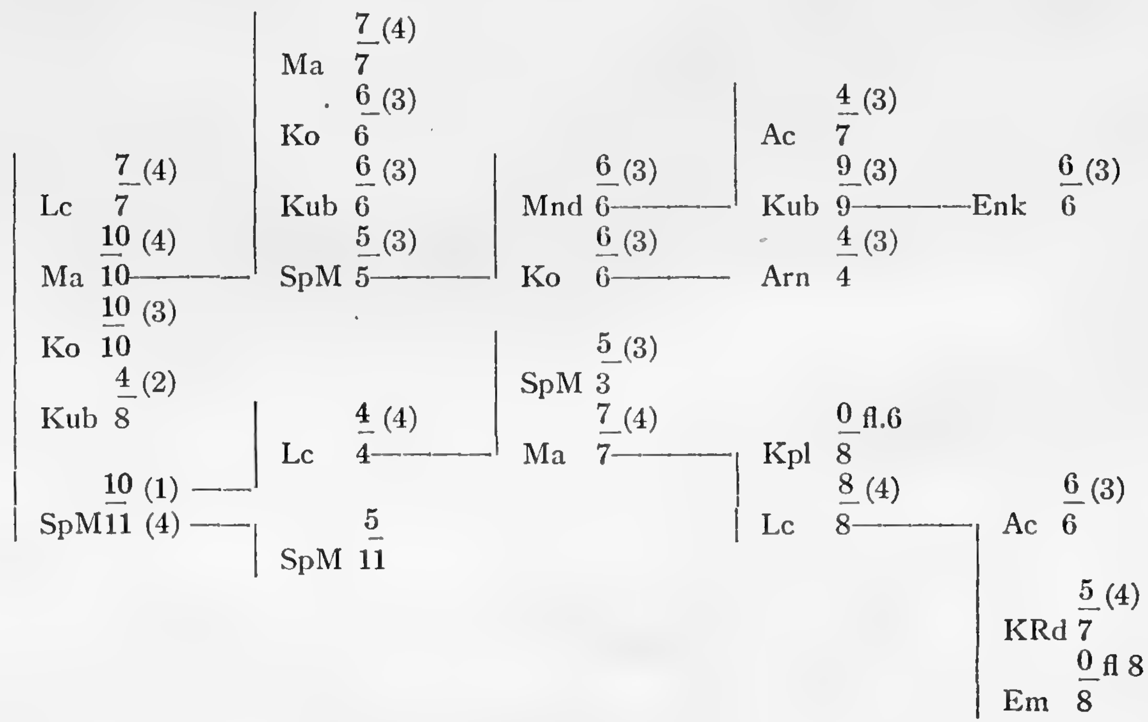


DIAGRAM 4.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORM XI

Puccinia graminis tritici
From Marquis wheat, Edmonton, Alta.
September 15, 1919.



Identified
August 20, 1920

Diagram 5.—A Series of Inoculations Resulting in the Identification of Form XII

Puccinia graminis tritici from Marquis wheat. Indian Head, Sask. August, 30 1920.

- Lc $\frac{6}{7}$ (4)
  - Lc $\frac{9}{9}$ (4)
    - Lc $\frac{8}{8}$ (4)
      - Lc $\frac{7}{7}$ (4)
        - Lc $\frac{6}{6}$ (4)
        - Kub $\frac{5}{8}$ (1)
        - SpM $\frac{4}{5}$ (1)
        - KRd $\frac{8}{10}$ (3)
  - Ma $\frac{8}{8}$ (4)
  - KRd $\frac{3}{8}$ (4)
    - Kub $\frac{3}{8}$ (1-4)
    - KRd $\frac{3}{8}$ (3)
    - Mnd $\frac{3}{10}$ (1)
  - Arn $\frac{7}{7}$ (4)
  - Mnd $\frac{0}{9}$ (0)
  - Kub $\frac{3}{8}$ (1-4)
  - Ac $\frac{7}{7}$ (4)
  - SpM $\frac{8}{8}$ (1-4)
  - Ko $\frac{4}{8}$ (3)
  - Enk $\frac{7}{7}$ (3)
  - Em $\frac{7}{7}$ (1)
  - Kpl $\frac{7}{7}$ (1)

Identified December 20, 1920.

DIAGRAM 6.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORMS XV AND XVIII

			Ma $\frac{6}{6}$ (4)	Mnd $\frac{0}{5}$ (0)		Kub $\frac{4}{4}$ (3)	
	Lc $\frac{4}{8}$ (4)	KRd $\frac{9}{9}$ (4)	Ko $\frac{6}{6}$ (3)	SpM $\frac{2}{7}$ (1)	Kub $\frac{6}{6}$ (3)	Mnd $\frac{1}{5}$ (1)	Enk $\frac{4}{7}$ (3)
Puccinia graminis tritici from Marquis wheat. Melfort, Sask. September 15, 1919.	Ma $\frac{2}{8}$ (4)	Lc $\frac{6}{7}$ (4)	Arn $\frac{6}{6}$ (1)	Kub $\frac{5}{5}$ (3)	SpM $\frac{0}{8}$ (0)	Ac $\frac{5}{6}$ (3)	Em $\frac{0}{6}$ (0)
	KRd $\frac{1}{9}$ (4)	Mnd $\frac{0}{8}$ (0)			Kub $\frac{7}{7}$ (3)	Lc $\frac{5}{5}$ (3)	KRd $\frac{5}{5}$ (3)
	Ko $\frac{4}{8}$ (4)	Ma $\frac{5}{5}$ (4)	Mnd $\frac{2}{2}$ (4)	Lc $\frac{8}{8}$ (4)	SpM $\frac{4}{4}$ (3)	Mnd $\frac{6}{6}$ (3)	Kpl $\frac{0}{7}$ (0)
			SpM $\frac{1}{7}$ (1)		Arn $\frac{3}{3}$ (3)		
					Ac $\frac{6}{6}$ (3)		
Identified August 6, 1920.					Em $\frac{8}{8}$ (3)		
					Enk $\frac{6}{6}$ (3)		

DIAGRAM 7.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORM XVII

Puccinia graminis tritici from Marquis wheat. Yorkton, Sask. July 15, 1921. Identified September 7, 1921.	Lc 8/8 (4)	Lc 11/11 (4)	Lc 10/10 (4)	
			SpM 8/8 (3)	KRd 0/19 fl. 3
			Ac 10/10 (3)	
			Enk 8/8 (3)	
			Kub 11/11 (4)	
		KRd 1/11 (4)		
		Ko 10/12 fl. 1 (3)		
		Arn 11/11 (4)		
		Mnd 10/11 (4)		
		Kub 6/12 fl. 4 (3)		
	Ma 7/7 (4)	Em 0/10 fl 10		
	Kpl 1/6 fl (1)			
	Arn 6/6 (3)			

DIAGRAM 8.—A SERIES OF INOCULATION RESULTING IN THE IDENTIFICATION OF FORM XVIII

(See Diagrams 6 and 14.)

DIAGRAM 9.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORM XIX

Puccinia graminis tritici
from Marquis wheat.
Indian Head, Sask.
September 15, 1919.

Identified
June 18, 1920.

Lc $\frac{2}{2}$ (4)

Lc $\frac{4}{4}$ (4)
Ac $\frac{4}{4}$ (4)
Ko $\frac{5}{5}$ (3)
Arn $\frac{8}{8}$ (4)
Kub $\frac{8}{9}$ (4)
Em $\frac{8}{11}$ (1)
SpM $\frac{10}{12}$ (3)
Enk $\frac{7}{8}$ (3)
KRd $\frac{0}{11}$ (0)
Mnd $\frac{8}{9}$ (3)
Ma $\frac{5}{10}$ (4)

Lc $\frac{7}{7}$ (4)
KRd $\frac{0}{5}$ (0)

Ma $\frac{6}{6}$ (1)
Mnd $\frac{8}{8}$ (3)
SpM $\frac{5}{5}$ (3)

DIAGRAM 10.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORM XXI

Puccinia graminis tritici from Marquis wheat. Winnipeg, Man. September 30, 1919.

- Lc $\frac{6}{8}$ (4)
  - Lc $\frac{8}{9}$ (4)
    - Lc $\frac{9}{9}$ (4)
    - KRd $\frac{1}{10}$ (4)
      - KRd $\frac{0}{9}$ (0)
  - Ma $\frac{10}{10}$ (4)
    - Ma $\frac{7}{7}$ (4)
    - Ko $\frac{9}{9}$ (4)
    - Mnd $\frac{6}{6}$ (3)
  - KRd $\frac{0}{15}$ (0)
  - Kc $\frac{10}{10}$ (3)
  - Kub $\frac{9}{9}$ (4)
    - Kub $\frac{7}{8}$ (4)
    - Ma $\frac{6}{6}$ (4)
      - Ma $\frac{5}{5}$ (4)
      - KRd $\frac{1}{8}$ (4)
      - Enk $\frac{3}{5}$ (1)
    - KRd $\frac{3}{6}$ (3)
  - Arn $\frac{5}{5}$ (4)
  - Mnd $\frac{11}{15}$ (3)
  - Ac $\frac{3}{4}$ (4)
  - Enk $\frac{10}{11}$ (1)
  - SpM $\frac{6}{8}$ (3)
    - SpM $\frac{8}{13}$ (4)
    - Enk $\frac{3}{13}$ (1)
    - KRd $\frac{1}{17}$ (3)
  - Em $\frac{6}{9}$ (2)

Identified June 18, 1920.

DIAGRAM 11.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORM XXIV

Puccinia graminis tritici from Marquis wheat. Saskatoon, Sask. July 17, 1921.	Lc $\frac{8}{8}$ (4)	Lc $\frac{9}{9}$ (3)	Lc $\frac{9}{9}$ (4)
	Ma $\frac{9}{9}$ (4)	Ko $\frac{8}{8}$ (2)	SpM $\frac{7}{7}$ (4)
	KRd $\frac{3}{6}$ (4)	Arn $\frac{8}{8}$ (3)	Enk $\frac{6}{6}$ (3)
	Kub $\frac{6}{7}$ (3)	Mnd $\frac{10}{10}$ (3)	
	Em $\frac{0}{10}$ (8)	Kub $\frac{4}{4}$ (3)	
	Kpl $\frac{2}{10}$ (1)	KRd $\frac{1}{7}$ (3)	
		Ac $\frac{8}{8}$ (3)	
Identified September 7, 1921.			

(Lines in the diagram join Lc 8 to the group Lc, Ko, Arn, Mnd; KRd 6 to the group Kub, KRd; Kub 7 to Ac; and Lc 9 in the second series to the group Lc, SpM, Enk.)

DIAGRAM 12.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORM XXIX

Puccinia graminis tritici from *Hordeum jubatum* Vegreville, Alta. September 11, 1920.

- Lc 4/6 (4)
  - Lc 4/6 (4)
    - Lc 4/10 (4)
      - Lc 6/7 (4)
      - KRd 1/8 (3)
        - KRd 1/10 (3)
      - Arn 7/8 (3)
      - Mnd 7/10 (1) (4)
        - Lc 2/3 (4)
          - SpM 2/3 (1) (4) —SpM 8/9 (4)
          - Mnd 4/8 (1-4)
          - Kub 8/8 (1-4)
        - Mnd 7/8 (1-4)
        - SpM 8/9 (1) (4)
          - SpM 9/10 (1-4)
          - Mnd 10/10 (1-4)
      - SpM 6/9 (3)
    - KRd 1/10 (3)
    - Arn 8/10 (4)
    - SpM 6/8 (1-3)
    - Mnd 9/10 (1-3)
  - Ma 7/7 (4)
  - Kub 9/9 (4)
  - Ac 8/8 (4)
  - SpM 7/7 (1-4)
  - Ko 10/10 (3)
  - Arn 10/10 (4)
    - Arn 6/8 (4)
    - Mnd 8/8 (1) (4) — Lc 2/10 (4) — Mnd 3/10 (1)
    - SpM 7/7 (1-4)
  - Enk 8/9 (3)
  - Em 8/8 (1)
  - Kpl 9/9 (1)
- Kub 10/10 (1-3)

Identified June 6, 1921.

DIAGRAM 13.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORMS XXX AND IX

Puccinia graminis tritici from Marquis wheat.
Carlyle, Sask.
September 22, 1920.

Identified
October 26, 1921.

Ma	$\frac{6}{8}$ (4)
KRd	$\frac{2}{7}$ (3)
Arn	$\frac{6}{7}$ (4)
Kub	$\frac{8}{8}$ (4)
Ac	$\frac{9}{9}$ (4)
SpM	$\frac{3}{8}$ (4)
Em	$\frac{13}{18}$ (1) (4)
Kpl	$\frac{9}{9}$ (1)

Ma	$\frac{4}{7}$ (4)
KRd	$\frac{0}{10}$ (0)
Ko	$\frac{9}{10}$ (3)
Enk	$\frac{4}{7}$ (3)

Em	$\frac{5}{9}$ (4)

Em	$\frac{10}{10}$ (4)
Arn	$\frac{10}{10}$ (4)
KRd	$\frac{0}{9}$ (0)
Mnd	$\frac{2}{8}$ (2)
Kub	$\frac{1}{6}$ (1-4)

Lc	$\frac{3}{3}$ (4)
Em	$\frac{7}{8}$ (4)
Kub	$\frac{6}{6}$ (1-4)
Mnd	$\frac{7}{7}$ (1-4)
SpM	$\frac{7}{7}$ (1-4)

Kub	(1-4)
Mnd	$\frac{5}{8}$ (3)
KRd	$\frac{0}{9}$ (0)

Em	$\frac{10}{10}$ (3)
Arn	$\frac{8}{8}$ (1-4)
Mnd	$\frac{5}{5}$ (1-4)
SpM	$\frac{8}{8}$ (1-4)
Kub	$\frac{9}{10}$ (1-4)

Em	$\frac{10}{10}$ (4) (Cont'd)
Arn	$\frac{11}{11}$ (1-4)
Mnd	$\frac{10}{10}$ (1-4)
SpM	$\frac{9}{9}$ (1-4)
Kub	$\frac{11}{11}$ (1-4)

DIAGRAM 13 (*Continued*)

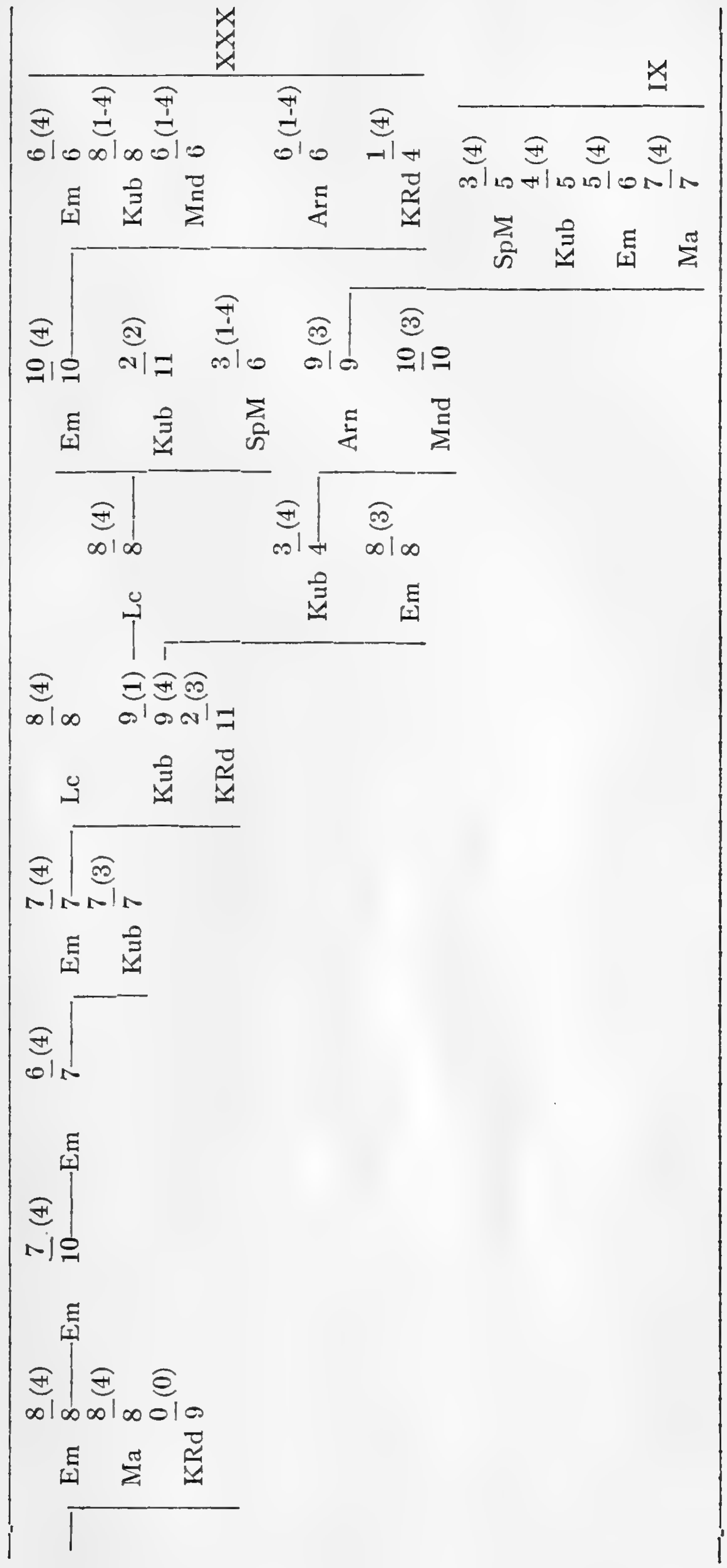


DIAGRAM 14.—A SERIES OF INOCULATIONS RESULTING IN THE IDENTIFICATION OF FORMS XVIII AND XXXII

		10 (4)		9 (4)		6 (4)		6 (4)		7 (4)		6 (4)
	Lc	10	Lc	9	Lc	7	Lc	6	KRd	7	KRd	6 —(Cont'd)
		9 (3)		10 (3)		0 (0)		5 (1-4)		8 (1-4)		8 (4)
	Ko	10	Ko	10	KRd	20	Arn	6	Kub	8	Lc	9
Puccinia graminis tritici		4 (4)		8 (1-4)						8 (1-4)		
from Marquis wheat.	Arn	10	Mnd	8					SpM	9		
Vermilion, Alta.		4 (1-4)		7 (1-4)						8 (1-4)		
September 11, 1920.	Mnd	10	SpM	7.					Mnd	8		
		8 (1)		7 (4)		5 (1-3)						
	Em	8	Ac	7	Kub	5						
		8 (1-4)		4 (3)		4 (4)						
	SpM	10	Enk	8	Ac	8						
		8 (1)		5 (3)		3 (1)						
	Kpl	8	KRd	5	Mnd	8						
						1 (4)						
		3 (4)		7 (1)	KRd	10						
Identified	KRd	7	SpM	7		10 (1)						
May 21, 1921.				8 (1-4)	SpM	11						
			Kub	8		2 (4)						
					Ma	10						

DIAGRAM 14 (*Continued*)

	8 (3)		9 (4)		7 (4)		5 (4)		7 (4)		8 (4)		17 (4)
KRd	10	Ma	11	Lc	9	Lc	6	Lc	7	Lc	8	Lc	17
			0 (0)		0 (0)		0 (0)		0 (0)		2 (3)		12 (3)
		Arn	10	SpM	5	SpM	4	Mnd	9	Kub	3	Enk	14
	8 (4)		0 (0)		1 (3)		0 (0)				0 (0)		13 (3)
Lc	9	Mnd	10	Mnd	6	Arn	10			Kpl	10	Ac	13
			0 (0)		0 (0)		0 (0)						10 (3)
		SpM	10	Arn	6	Mnd	6					Ko	12
			0 (0)		5 (3)								
		Enk	8	Enk	7								

Attention should be drawn to two other rather striking facts, evident in the diagrams. It will be seen that Khapli, an emmer from India, is resistant to every form of rust found, while Little Club is completely susceptible in all cases. From the standpoint of the plant breeder, it is unfortunate that Khapli is very difficult to hybridize successfully with the bread wheats.

Importance of Forms Isolated

The factors which determine the importance of a biologic form are its varietal range and virulence, and its distribution and frequency of occurrence.

Varietal Range and Virulence.

A glance at Table III will show that rusts from different localities vary greatly in their parasitic behaviour to wheat varieties. Marquis, a wheat quite susceptible to practically all forms of rust in Western Canada, is highly resistant to a form found at Indian Head. Four distinct biologic forms were found at Saskatoon; one of these infected White Spring emmer very heavily, while another scarcely infected it at all. In the same way, Kanred showed heavy normal infection at Brandon, Yorkton, Moose Jaw, and Edmonton, and complete immunity at Winnipeg, Prince Albert, and Lacombe. One of the forms, XV, was very virulent on all but one of the varieties inoculated, while another, III, was so weak that it could attack only a few varieties successfully. Several forms differed from one another only in their action on one or two varieties, but these differences were always definite and consistent.

Usually more than one biologic form was found on the same variety, sometimes even on the same plant. From one rusted plant collected at Rosthern, Saskatchewan, were isolated three distinct forms, III, IX, and XVII. On the other hand, the same form was present on a great variety of hosts and apparently was not changed in any way by association with this host. One form collected on barley, emmer, club wheat, and various other varieties of spring and winter wheats, as well as on wild grasses, gave the same reaction in all cases, whether taken from the wild grasses of northern Alberta or from the hard spring wheats of southern Manitoba. This constancy of behaviour will be more fully discussed in a later section of this paper.

Distribution and Frequency.

The geographical distribution of the various biologic forms is still imperfectly known. However, tentative maps have been prepared showing the areas in which the more frequently occurring forms have been collected. These have been made by the simple expedient of connecting with a broken line the more outlying points at which collections have been made. The boundaries so arrived at will, no doubt, be extended by further exploration. Indeed, it seems probable that no southern boundary exists, and that in some cases, at least, the northern boundary may coincide with the limits of the wheat-growing area. On the other hand, it is probable that the frequency of occurrence will diminish towards the outlying parts of the areas involved, although, in special cases, natural barriers may possibly interpose an abrupt limit. It must be noted, further, that the date of occurrence in a given locality possibly varies with remoteness from the point of origin of the infection. This may explain why collections in the Calgary to Edmonton district of Alberta are rarely possible before September. Such conditions are, of course, extremely fortunate for the region concerned, since infection occurring thus late cannot do any serious damage to the crop.

In Fig. 1, A. is shown the area from which collections of a rather virulent form, XVII, have been made. This is by far the most widely distributed of all the forms isolated. It is found in 26 distantly separated districts of Manitoba, Saskatchewan, and Alberta, embracing a variety of climatic conditions, especially in regard to rainfall. As already pointed out, the area delimited on the map may safely be taken as a very conservative index of distribution; in many places outside this area, but one collection of rusted material has been made. The persistance of Form XVII is shown by the fact that once it has been found in any locality, collections in one or more succeeding seasons have rarely failed to demonstrate its recurrence.

Within the same area are included, of course, many other forms; eight have already been found.

In Fig. 1, B. is shown the area in which have been found 6 forms (I, IX, XVII, XXI, XXIX, XXX) all of which cause the same infection upon all the bread wheats, as may be seen by reference to Table III. That is not to say that these 6 forms are identical, since, as may also be seen, they vary greatly in their parasitism towards other varieties. The great importance of this group will be apparent when it is pointed out that they include 70 per cent. of the rust collections made, and cover practically the whole area now occupied by the grain growing industry. In fact, this area will probably continue, for a long time, to be the main wheat centre. In portions of southern Alberta and Saskatchewan, on account of the rather arid conditions which prevail, wheat will probably never be the crop of first importance. With regard to the more northern and western districts it has been pointed out already that rust infection seldom

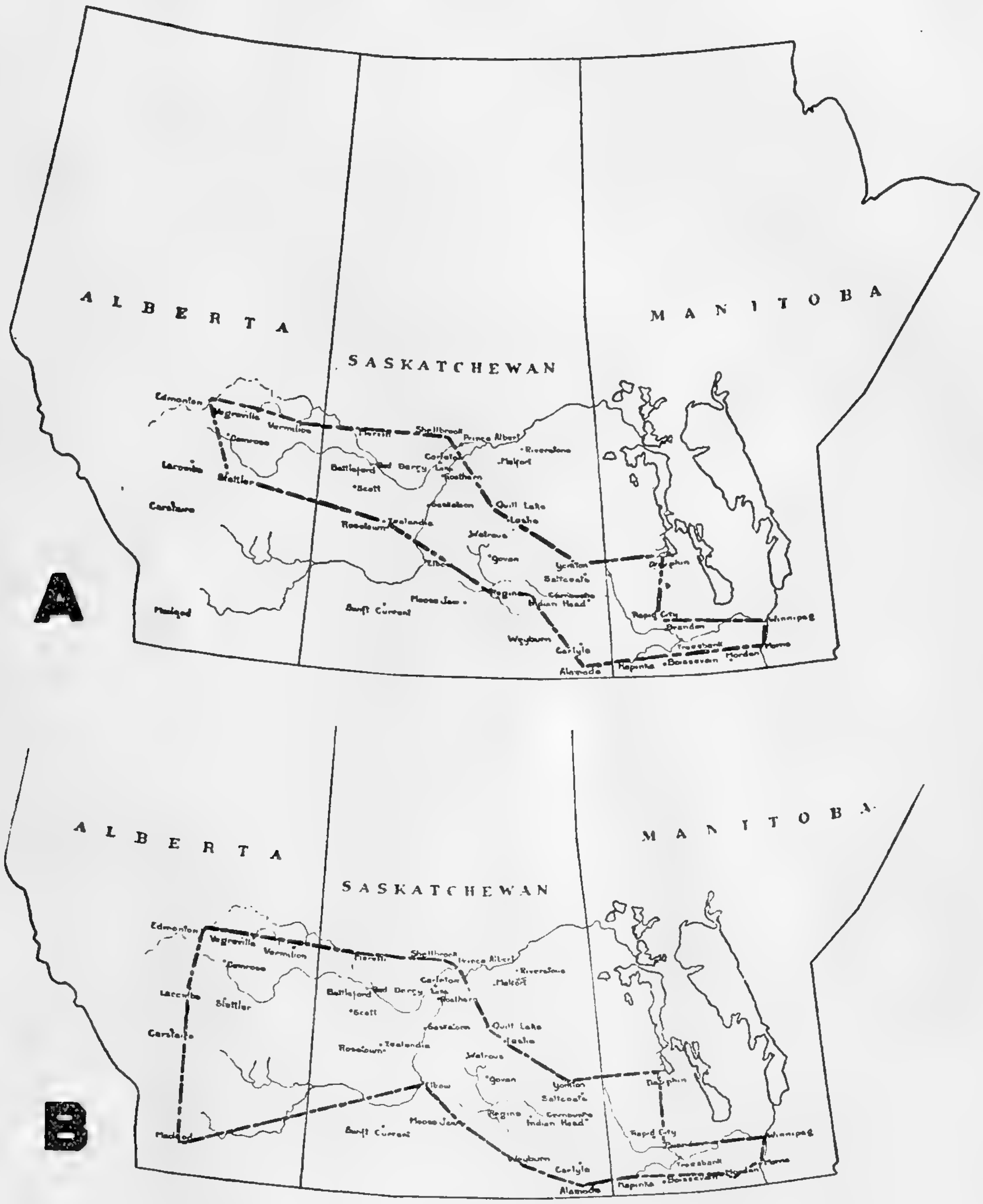


Fig. 1. A. Distribution of Form XVII (virulent) in area explored.
B. Area in which have been found the 6 dominant forms.

occurs early enough in the season to cause material damage. Obviously, the group of rust strains just considered should constitute the first point of attack for the plant breeders. The winning of this objective should go a long way towards the solution of the general problem.

The distribution of the 8 remaining forms is shown in Figs. 2, A and B. A key to the symbols employed is given in the lower right-hand corner. On the whole, these forms were rather widely scattered, although Form IX, which attacks emmer heavily, apparently was more prevalent in the eastern half of the wheat area than

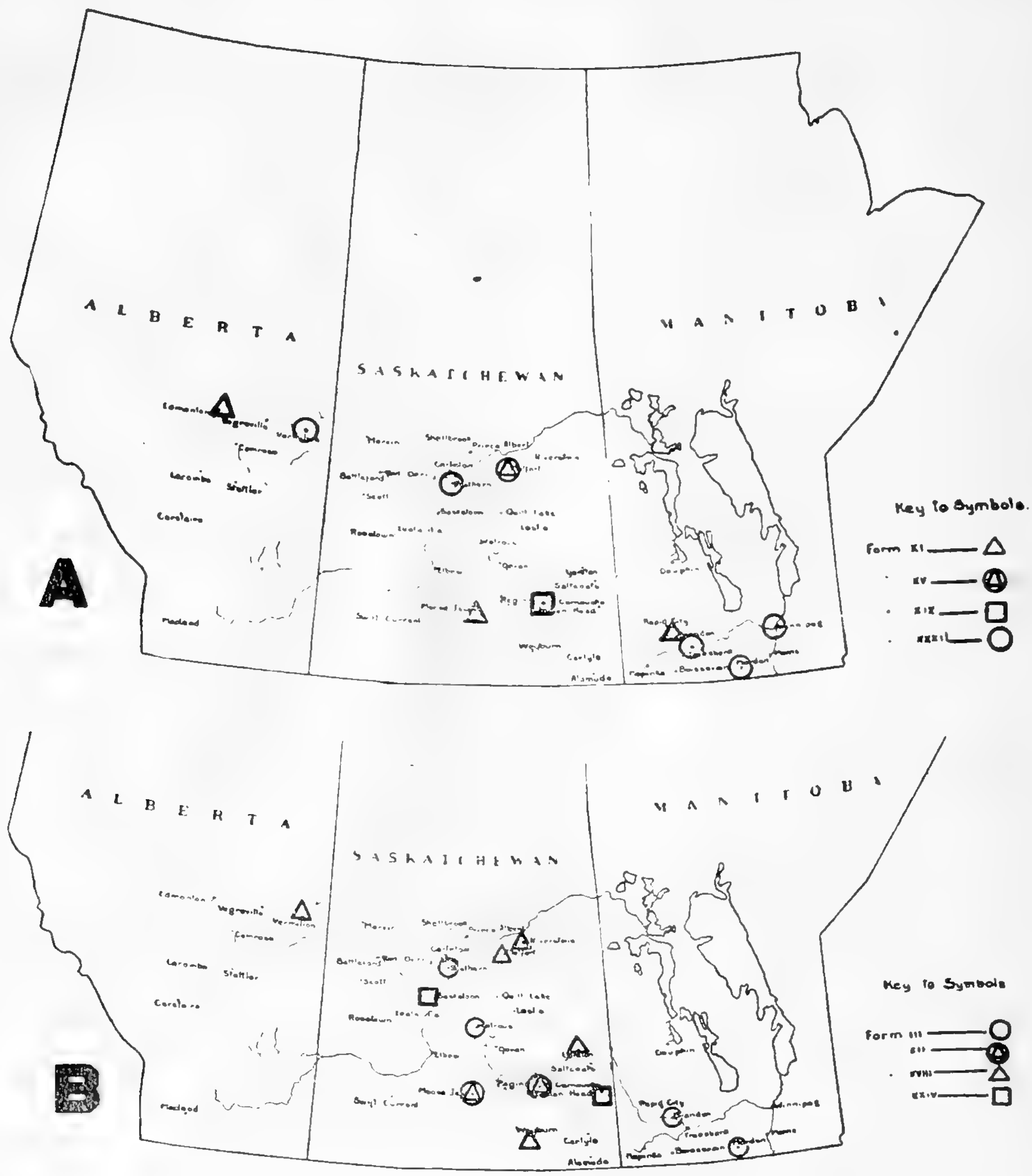


Fig. 2. Localities in which have been collected the forms not included in Fig. 1.

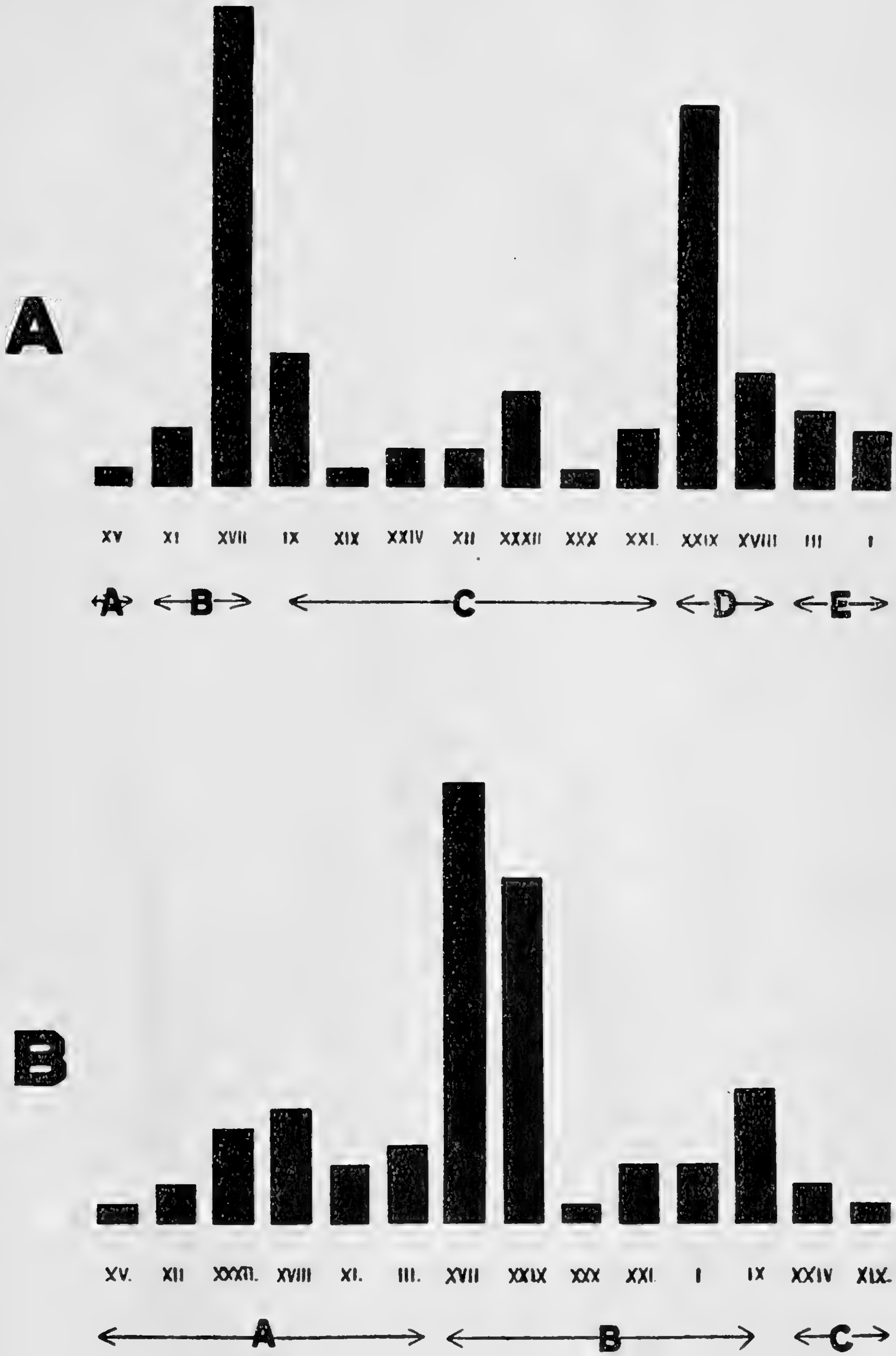


Fig. 3. Frequency of occurrence and order of virulence of forms isolated. Comparative frequency indicated by height of columns. Forms arranged from left to right in order of virulence to all differential hosts (upper figure) and to bread wheats (lower figure).

in the western half. Three of the forms, XV, XIX and XXX, were each found in but one place; but, in all other cases, the same form was found in two or more different places. This is what we would expect in the prairies, where the high winds, the absence of natural barriers between the wheat-growing areas, and the similarity of the wheat varieties grown make it extremely unlikely that any strain will be confined to one small fixed area. This, of course, is advanced merely as a tentative hypothesis, to be tested by further survey. It is possible that climatic factors may determine to some extent the geographical limits of these biologic forms, and the areas invaded by them may be more or less fixed.

A graphic representation of frequency of occurrence and virulence is given in Fig. 3. The comparative frequency of the forms is indicated by the height of the columns. In Fig. 3, A. the forms are arranged from left to right in order of virulence toward all test wheats. A sub-grouping of strains of approximately equal virulence is indicated by the subdivisions, A, B, C, D, and E. The same arrangement with respect to their reactions toward the test wheats of the bread group (*i.e.*, excluding durum varieties, spelt and einkorn) is given in Fig. 3, B. Particular interest attaches to sub-group B, which includes the 6 strains referred to in the distribution map, Fig. 1, B. The fact that this, the most important sub-group, is six places removed from the most extreme type of virulence, is in itself matter for encouragement.

In Table IV is given a summary of the information relating to the forms isolated which, from the practical standpoint, appears to be of greatest importance. This includes a statement of the number of times each form was isolated, the districts in which collected, the effect on common and durum wheats, and remarks suggestive of the probable effect of each form in the field.

Infection of Grasses

Some of the most virulent of the forms of stem rust isolated were collected on wild grasses. Stakman and Piemeisel (59) found *P. graminis* present on about 35 species of grasses in the United States, 26 of which species they were able to infect artificially with *P. graminis tritici.* There is absolutely no doubt that the wild grasses have a marked effect upon rust epidemics. In late fall and early spring hey present suitable host tissue for the fungus when the spring wheat crop is not available. They may originate seasonal infection by permitting the overwintering of the rust in the mycelial or uredinio-

Table IV.—Summary of Points of Special Economic Importance

Form	No. of times isolated	Districts in which collected	Effect on Bread Wheats	Effect on Durums	Probable Effect in Field
I	3	Brandon, Manitoba Carnoustie, Sask. Morris, Manitoba	Heavy infection	Moderate resistance. Kubanka fairly heavily infected.	Limited distribution but serious where present.
III	4	Brandon, Man. Morden, Man. Rosthern, Sask. Watrous, Sask.	Very heavy infection	Decided resistance	Limited distribution, but very serious where present.
IX	7	Brandon, Man. Carlyle, Sask. Edmonton, Alta. Leslie, Sask. Rosthern, Sask. Saskatoon, Sask. Winnipeg, Man.	Moderate resistance	Moderate resistance. Mindum and Kubanka fairly heavily infected	Fairly wide distribution. Seldom serious except where emmer is grown.
XI	3	Brandon, Man. Edmonton, Alta. Moose Jaw, Sask.	Very heavy infection	Very heavy infection	Limited distribution, but very serious where present.
XII	2	Indian Head, Sask. Moose Jaw, Sask.	Heavy infection	Moderate resistance. Acme fairly heavily infected.	Limited distribution, but serious where present.
XV	1	Melfort, Sask.	Very heavy infection	Very heavy infection	Very limited distribution, but extremely serious where present.
XVII	26	Alameda, Sask. Camrose, Alta. Carleton, Sask. Dauphin, Man. Edmonton, Alta. Govan, Sask. Howell, Sask. Indian Head, Sask. Morris, Man. Napinka, Man. Prince Albert, Sask.	Heavy infection	Very heavy infection on all but Acme	Very wide distribution and very serious where present.

TABLE IV (*Continued*)

Form	No. of times isolated	Districts in which Collected	Effect on Bread Wheats	Effect on Durums	Probable Effect in Field
XVII (Continued)		Rapid City, Man. Red Berry Lake, Sask. Rosthern, Sask. Saltcoats, Sask. Saskatoon, Sask. Shellbrook, Sask. Stettler, Alta. Vermilion, Alta. Winnipeg, Man. Yorkton, Sask. Zealandia, Sask.			
XVIII	6	Melfort, Sask. Riverstone, Sask. Saskatoon, Sask. Vermilion, Alta. Weyburn, Sask. Yorkton, Sask.	Heavy infection	Decided resistance	Moderate distribution and serious where present.
XIX	1	Indian Head, Sask.	Very light infection	Heavy infection	Very limited distribution; practically no effect where present.
XXI	3	Alameda, Sask. Carleton, Sask. Winnipeg, Man.	Heavy infection	Heavy infection on all but Acme	Limited distribution but serious where present.
XXIV	2	Carnoustie, Sask. Saskatoon, Sask.	Light infection	Very heavy infection	Limited distribution and not very serious where present.
XXIX	20	Brandon, Man. Carlyle, Sask. Edmonton, Alta.	Heavy infection	Variable infection	Very wide distribution and serious where present.
XXX	1	Carlyle, Sask.	Heavy infection	Variable infection	Limited distribution but serious where present.
XXXII	5	Morden, Man. Rosthern, Sask. Treesbank, Man. Vermilion, Alta. Winnipeg, Man.	Heavy infection	Variable infection	Moderate distribution and serious where present.

spore stage. They contribute largely to the general dissemination of the disease throughout the season. Certain grasses may even harbour special biologic forms.

Since nothing was known concerning the reaction of most of the biologic forms on grasses, 29 species were inoculated with 3 of the most prevalent and diverse forms of rust found in Canada, IX, XVII, and XVIII. The results are given in Table V, and show that there are only slight differences in the infection capabilities of these 3 forms towards the grasses tested. This is in sharp contrast to the behaviour of the same biologic forms on the 12 wheat varieties used as differential hosts. Of course, it must be borne in mind that this list of differential hosts was arrived at only after much experimentation. In an early stage of her investigations, the author tested 120 varieties of bread wheats with 6 collections of wheat rust without finding any evidence of biologic specialization. It is therefore quite possible that further work may discover differential hosts also among the wild grasses.

Discussion of the Principal Issues

The study of biologic forms of the pathogene causing wheat stem rust (*Puccinia graminis tritici*s) in Canada suggests that climate is not a controlling factor in the distribution of these forms. The 14 forms collected in various parts of Western Canada proved to be identical with forms isolated by Stakman and Levine in collections made from widely separated points in both northern and southern United States. This was rather interesting as, before carrying out this experiment, it was thought that rust found in the protected foothills of the Rockies and in northwestern Alberta might be quite different from that found in the open plains of the Red River Valley of either Canada or the United States.

In connection with these studies, consideration was given to the old problem of the seasonal spread of rust from south to north. In case the rust moved northward in waves across the continent, and the biologic forms varied in point of origin, then it would be expected that they would appear at successive dates during the summer, varying with the remoteness of the point of origin. Accordingly, the place and date of collection of each form were carefully noted. Although in the three observed years no definite succession of biologic forms was found, yet it was interesting to note that the same biologic form, XVII, appeared first each year, having been collected as early as July 5, and a form attacking emmer heavily, IX, was always one of the

TABLE V.—RESULTS OF INOCULATIONS WITH *P. graminis tritici* IX, XVII, XVIII UPON GRASSES

Plant inoculated	*P. graminis tritici* IX		*P. graminis tritici* XVII		*P. graminis tritici* XVIII	
	Result	Character of Infection	Result	Character of Infection	Result	Character of infection
Agropyron caninum (L.) Beauv.	*10/25	Quite susceptible	16/18	Quite susceptible	12/20	Quite susceptible
Agropyron smithii Rydb.	1/2	Heavy	1/2	Heavy		
Agropyron spicatum (Pursh.) Rydb.	8/12	Heavy	1/16	Heavy	3/18	Heavy
Agropyron tenerum Vasey	20/25	Heavy	16/29	Heavy	19/33	Heavy
Agrostis alba L.	0/18		0/16;2	Flecks indistinct	0/32	
Anthoxanthum odoratum L.	0/22		0/19		0/28	
Bromus carinatus H and A	8/12;7	Minute uredinia Flecks distinct	12/29	Small uredinia Flecks distinct	13/26	Small uredinia Flecks distinct
Bromus inermis Leyss.	0/20;3	Very indistinct Flecks	0/18;4	Flecks indistinct	0/30	
Bromus pumpellianus Scribn.	0/28		0/30;6	Flecks indistinct	0/19;3	Flecks indistinct
Bromus unioloides (Willd.) H.B.K.	0/16	Flecks indistinct	0/17;4	Flecks indistinct	0/32	
Bromus villosus Forsk.	8/15;4	Uredinia small Flecks distinct	8/24;4	Uredinia small Flecks distinct	0/26	
Dactylis glomerata L.	0/21		0/26;4	Flecks indistinct	0/18	
Elymus canadensis L.	7/40	Heavy	10/39	Heavy	5/23	Heavy
Elymus curvatus Piper	20/31	Heavy	10/36	Heavy		
Elymus robustus Scribn.	12/19	Heavy	10/26	Heavy	7/19	Heavy
Elymus virginicus L.	5/24	Quite susceptible	23/32	Quite susceptible	1/12	Quite susceptible

*The fractions indicate the number of leaves inoculated (denominator) and the number developing consequent uredinia (numerator).

TABLE V (*Continued*)

Plant inoculated	*P. graminis tritici* IX		*P. graminis tritici* XVII		*P. graminis tritici* XVIII	
	Result	Character of infection	Result	Character of infection	Result	Character of infection
Festuca elatior L.	0/30		0/19		0/25	
Hordeum dactylon	9/16	Heavy	6/18	Heavy	8/30	Heavy
Hordeum pusillum Nutt.	4/16	Heavy	4/22	Heavy	9/16	Heavy
Hordeum murinum L.	12/16	Heavy	16/23	Heavy	18/29	Heavy
Hystrix patula Moench.	1/18	Quite susceptible	6/25	Quite susceptible	8/26	Quite susceptible
Lolium perenne L.	0/29		0/25		0/36	
Poa annua L.						
Poa compressa L.	0/12		0/9			
Poa pratensis L.	0/22		0/17		0/28	
Poa triflora Gilib.	0/16		0/22		0/17	
Sporobolus cryptandrus (Torr) A. Gray	0/16;11	Flecks indistinct	0/22		0/17;10	
Stipa lepida	0/42		0/34		0/8	
Stipa viridula Trin.	0/30		0/17		0/31	

last to be collected, seldom appearing before September. With these exceptions, the experiment has shed little additional light on this problem of the seasonal spread of rust.

The constancy of behaviour of the biologic forms is one of the striking facts emerging from these investigations. Association of the same form with a great variety of hosts, in widely separated localities, was without apparent effect. Inoculations on the test wheats invariably gave the same result, whether the inoculum was obtained from the same varieties, or from very different hosts on which the fungus had been cultured for several generations. This experience supports the conclusions of Stakman, Piemeisel and Levine (6), based upon their extended investigations of this point. However, the idea has been frequently expressed that a permanently rust-resistant wheat variety cannot be produced by the plant breeder, owing to the plasticity of the rust, which gives it facility in adapting itself to new conditions, and it is of interest, therefore, to examine one or two ways in which such an erroneous impression may have become current.

Let us suppose that a person unfamiliar with the exacting technique required in the study of biologic forms collects wheat stem rust from Marquis wheat, and that the biologic forms thus fortuitously obtained are III and IX. Suppose now that with this mixture he inoculates Kanred (common wheat), Arnautka (durum) and Emmer. The results, expressed by our formula, would be as follows:

Form	Ma	KR	Arn	Em
III	3	3	1	1
IX	3	0	3	4

Thus in every case the variety concerned would show moderate susceptibility, with well formed pustules of one or other of the forms, which, however, would appear identical to the observer. The very small pustules of Form III on Arnautka and Emmer might escape notice, or be set down as poorly developed pustules of the dominant type. Let us suppose, further, that our interested observer transfers material from Kanred to fresh plants of Arnautka and emmer, or from the well developed pustules of Arnautka or emmer to Kanred. In the first case, he would find high resistance, and in the second immunity, and he might easily conclude that the fungus had changed its virulence. This is merely an example of many possible accidental combinations of wheat varieties and mixtures of biologic forms which might give rise to wrong conclusions.

Another possible way in which an observer may be misled with regard to the constancy of biologic forms is in the interpretation of morphological variations in the urediniospores. Resistant host plants, and unfavourable cultural conditions affecting the development and vigour of the fungus, may cause the urediniospores formed to be appreciably smaller. However, as soon as the rust is returned to a congenial host the spores developed are normal in size from the outset. No more significance is to be attached to such variations in size than can be attached to variations in the size of the wheat plant itself when grown in different soils of varying degrees of fertility. These variations within a given form are not to be confused with true morphological distinctions between different biologic forms, of which reports have been published by Stakman and Levine (55) and Melchers and Parker (45).

The 6 biologic forms of rust collected in the area mapped in Fig. 1, B. deserve the first attention of Canadian plant breeders. They cover practically the whole of the main wheat-growing areas of the West. All 6 forms cause heavy infection, "3-4," upon all the bread wheats, except upon Kanred, a winter wheat. There is, in fact, a tendency for all the hard spring wheats to act as a group with reference to resistance or susceptibility to any biologic form, or group of forms. Their common susceptibility to this important group of biologic forms is, of course, unfortunate; but, on the other hand, the tendency to a common reaction towards a group of forms gives reason to hope that when a spring wheat is produced which is resistant to one of these 6 forms, it will prove resistant likewise to the others. This hope appears the more reasonable in that Kanred is consistently immune to all members of this group. Since these forms included 70 per cent. of all the rust collections made, and since the bread wheats comprise practically the whole of the Canadian wheat crop, it is apparent that the production of a spring wheat resistant to this group, and satisfactory in its agronomic and milling qualities, must potentially effect a tremendous reduction of the annual losses from wheat rust.

That rust resistance is an inherited character was conclusively proved by Biffen (4). Recently, Puttick (47) attempted an analysis, from the genetic standpoint, of the reaction of the F_2 generation of a cross between a common and a durum wheat to two of the biologic forms of *Puccinia graminis* isolated by Stakman and Levine. The parental plants were in each case resistant to one of the biologic forms and susceptible to the other, reacting reciprocally in this respect. The author in his summary states that, "All combinations of susceptibility and resistance of individual F_2 plants to the two biologic forms appeared. Out of a total of 388 plants 35 were highly resistant to both forms of rust. This makes it reasonable to assume that varieties resistant to more than two biologic forms may be produced by hybridization."

In conclusion, attention is directed to the fact revealed in Table III that genetic material bearing the necessary factors for rust resistance is available in the common and durum wheats (without having recourse to the difficultly hybridizable einkorn and emmer) for 11 of the biologic forms isolated in Canada. Of the remaining 3 forms one is of rare occurrence, and the other two are of not more than moderate frequency. It will be seen that Kanred, a variety of winter wheat, is *completely immune to all 6 forms* of the important predominating group discussed above. Thus, the required tools are at hand. The task is by no means impossible of accomplishment. For the patient and painstaking labour of the plant breeder it promises rich reward.

Summary of Part I

1. Fourteen biologic forms of *Puccinia graminis tritici* have been demonstrated by infection experiments to be present in Canada.

2. All of these forms, as well as some others, are found in the United States.

3. Strain XVII was always the first form to appear each season, and IX one of the last forms to be collected. This suggests that the former may be more local in origin and the latter carried by winds from farther south.

4. The geographical limits of the forms isolated have been tentatively mapped, but will, no doubt, be extended by further exploration.

5. A rather virulent form, XVII, was found to be quite widely distributed, being collected in twenty-six different localities of Manitoba, Saskatchewan and Alberta.

6. Preliminary infection experiments with 29 species of grasses are reported.

7. As Stakman has pointed out, "Methods of breeding for rust resistance must now be changed fundamentally. The breeder must know and work with those forms of rust which occur in the region for which his new variety is intended."

8. The six forms, I, IX, XVII, XXI, XXIX, XXX, all of which give the same reactions on the bread wheats, constitute 70 per cent. of all the collections. Thus the production of a spring wheat variety

resistant to any one (and therefore presumably to all) of these six strains must potentially effect a tremendous reduction in the annual losses from wheat rust.

9. Genetic material bearing the necessary factors for rust resistance is readily accessible to the plant breeder. Kanred, for example, is immune to all of the 6 biologic forms predominating in the principal wheat-growing areas.

PART II

The Development of the Parasite within the Tissues of Resistant and Susceptible Hosts

Historical Introduction

Marshall Ward (63, 66) was the first investigator to carefully work out, and accurately interpret, the intimate relationship between the host and the rust parasite. The most important conclusion arising out of his early work was that resistance has nothing to do with anatomy, but depends entirely on the physiological reactions of protoplasm of the fungus and of the cells of the host. Later (66) in investigations which refuted the "mycoplasm hypothesis" of Eriksson, he worked out for the first time the complete histology of the uredinial cycle of a rust fungus (*P. dispersa*).

Since his time considerable work has been done on the effects of different rusts upon both congenial and uncongenial hosts. Miss Gibson (26) inoculated a large number of unrelated plants with the spores of *Uredo chrysamthemi*, as well as of other rusts, and found in all these cases that the germ tube entered the stoma in the same way as it did in a normal infection on the proper host of this fungus. However, the after course of events was quite different. No haustoria were formed, the hyphae appearing to die as soon as they came in contact with a cell. Consequently no pustules were formed. The failure of the fungus to produce haustoria was suggested to be due to some poisonous or repellent substance emitted by the cells. The power to form haustoria was, therefore, taken as an index of infection capacity; because if the fungus cannot use the host-plant as food it must shortly die of starvation. In the case of resistant varieties of Chrysanthemum the germ tube entered and developed a mycelium with haustoria, just as in the infection of a susceptible variety, but the mycelium was unable to spread further, owing to the host tissue in the neighbourhood having been killed. The author concluded that whenever a germ tube of any rust fungus enters any plant but its own proper host, a struggle goes on resulting in the death both of the host, locally, and of the parasite. The more closely related the host is to the proper host of the fungus, the longer and more extensive will be the struggle.

Miss Marryat (43) found that *P. glumarum* manages to make good its entry into semi-immune wheats, to produce comparatively large and numerous hyphae, and even in rare cases to form small or abortive pustules, but that, sooner or later, it is starved to death by the breaking down and death of the host tissue in its vicinity.

Stakman (52), working with *P. graminis*, observed that in a resistant host a limited number of cells adjoining the point of infection are killed, and the fungus fails to develop normally; while, in a susceptible host, the fungus grows vigorously without immediate serious injury to the host tissue. To explain this he advanced his "hypersensitive" theory, which assumes that in resistant forms the host cells are hypersensitive to the fungus; that is, when the infecting hypha enters the cells of a resistant form the cells immediately begin to disintegrate. From this point of view the meaning of the terms "resistance" and "susceptibility" could perhaps be more clearly expressed, respectively, by the terms "intolerance" and "tolerance." The immediate death of intolerant cells on penetration by the fungus leads to the starvation and death, in its turn, of the parasite. The net result is a failure of the infection, a demonstration of "resistance."

This local killing of intolerant tissue may be clearly seen in our Plates I, II and III, in the form of chlorotic areas on the resistant varieties.

Since the publication of the papers reviewed above several wheats have been discovered which display a considerably greater immunity than those described by these authors. It is a matter of common observation that immune wheat varieties, when inoculated with *P. graminis tritici*, show characteristic flecks. The lesions produced are not identical on all resistant varieties, but the presence of larger or smaller dead areas, with small uredinia, or even no uredinia, is characteristic of them all. In extreme cases of incompatibility the leaf area involved is usually so small that no indication of it can be seen with the unaided eye. Such is the case of Kanred wheat when inoculated by Forms I, IX, XVII, XIX, XXI, XXIV, XXIX and XXX, forms to which it is extremely resistant. As flecks can rarely be found upon this wheat the question has naturally been raised as to whether the rust fungus actually enters this variety.

Miss Allen (1) has recently reported an investigation bearing on this point. She worked with a form of stem rust at Berkeley which produced heavy infection on some wheat varieties, but which on Kanred failed even to produce flecks. She found that although the urediniospores germinated readily on these Kanred leaves, and the germ tubes made their way directly to the stomata, relatively few appressoria entered the stomatal slit. On measurement she found the stomatal aperture in Kanred to be extremely long and narrow, and that of Mindum, a less resistant variety, to have an average width about twice that found in Kanred. This work brings up again the theory which Marshall Ward and his students appeared to have conclusively disproved, viz., that resistance may depend on anatomical adaptations. Our own preliminary investigations, reported in the following pages, tend, however, to support the conclusions of Ward.

Histological Material and Methods

Two wheat varieties were used for the experiment, Marquis, a wheat very susceptible to Form XVII, and Kanred, a wheat very resistant to the same form. Seedlings of these two varieties were inoculated in the manner described by Stakman and Piemeisel (59). Portions of the inoculated leaves were removed and fixed daily until uredinia made their appearance on Marquis. As a rule, this took place about the eighth day. Kanred seldom showed any signs of having been inoculated.

In this way the life history of the fungus was studied from the period of germination up to the formation of spores in Marquis, and until death of the fungus in Kanred.

For fixing chromo-acetic acid and Flemming's weaker solution were used. On the whole, the best results were obtained with the former solution, in concentrations varying from one per cent. to one-tenth per cent. solution.

The leaves were embedded in paraffine in the usual manner and the sections cut from 5 to 10 u thick.

The chief stains used were:

1. Safranin and light green.

2. Flemming's orange method (safranin, gentian violet and orange G).

3. Iron alum haematoxylin, counterstained with safranin, eosin or orange G).

Normal Infection of a Susceptible Host

The development of the fungus on a susceptible (tolerant) host is considered normal infection. The infection of Marquis wheat (susceptible) by Form XVII will be described here, and the abnormal condition found in Kanred wheat (immune) left for consideration in the succeeding section.

The germination of the urediniospore on the epidermis usually takes place within the first twenty-four hours. The tips of the numerous germ tubes can be seen preparing to enter the stomata during the second day, and by the third day infection is well established.

When the spore germinates, two germ tubes frequently appear, but one develops more quickly than the other, and the growth of the weaker one is soon arrested. The surviving germ tube grows rapidly, following the epidermis quite closely for long distances, often for the length of ten to twelve epidermal cells before entering a stoma. When the tip reaches a stoma instead of entering directly it swells up and forms an appressorium. Here practically the entire protoplasmic contents of the germ tube are concentrated (Plate IV, 5 and 6). Bolley (6) has depicted the germ tube passing straight through the stoma to the mesophyll cells below. Further, he says that the germ tube from these urediniospores "may bore its way through the skin of a wheat plant and thus start another point of infection." Neither of these phenomena has been observed by the writer. An appressorium has been formed in all cases observed, and infection was always brought about by way of a stoma.

The germ tube is not always uniform in thickness. Swellings often appear in places, usually depressions in the leaf surface, that are not directly above a stoma (Plate IV, 7). These swellings have the appearance of young appressoria, as the protoplasm aggregates here more densely than in the other parts of the tubes. In a few it was observed that a swelling appeared above a stoma, as in the formation of an ordinary appressorium, but the tube did not enter the leaf at this point but continued to grow in length, entering by another stoma.

From the appressorium a thin process passes through the stomatal slit to the substomatal space (Plate IV, 5). As soon as the neck has passed through the aperture it enlarges to form the sub-stomatal vesicle (Plate IV, 5, 8 and 9). Into this vesicle the whole contents of the spore are poured, and the entry of the fungus is completed. The germ tube and appressorium soon wither and are lost to sight.

The sub-stomatal vesicle now sends out at one or more points tube-like processes, the true infecting hyphae, into which the whole, or a part, of the vesicular protoplasm passes (Plate IV, 9). Usually these infection threads follow closely along under the epidermal cells, and send small knob-like or flattened haustoria (suckers) into the host cells (Plate IV, 10; Plate V, 12, 13, 14 and 15). It is by means of these haustoria that the fungus obtains its nutriment. Occasionally the hyphae strike straight across the sub-stomatal intercellular space and branch between the mesophyll cells (Plate IV, 9). Not many such cases were observed. When the infecting hypha forms a haustorium in the first cell with which it establishes contact we say that infection has taken place.

The next stage in the development of the infection is the branching of the hyphae between the cells of the leaf. This growth is accompanied, and indeed supported, by the sending out of many haustoria. The hyphae continue to grow very rapidly from the third to the seventh day, by which time they have usually attained their maximum development. During this period two distinct kinds of branches are seen, the short branches which ramify in the intercellular spaces between the palisade cells, and the long, almost straight hyphae which grow so quickly, and have such long segments, and so few branches, that they remind one, to use Ward's simile, of "runners in higher plants" (Plate V, 16). These runners are vacuolated but rarely septate. They seem to be more in the nature of distributive filaments. Haustoria are not developed by the quickly extending runners, but are abundantly formed by the short branches which fill the intercellular spaces between the cells.

About the fifth day the hyphae branch very rapidly, and begin to mass themselves in a dense weft beneath the epidermis, preparatory to the formation of a pustule. The epidermal cells are wedged apart, and by the eighth day the epidermis has been completely ruptured, after which the spores are shed in great profusion.

In the course of the developmental cycle just described the fungus does not seem to spread very far from the point of infection. Indeed, when large areas of the leaf are involved a number of points of entry can nearly always be found.

In the susceptible host there seems to be a ready adjustment between host and parasite during the early stages of the disease. In spite of the fact that the mycelium is growing vigorously the host cells are not severely injured. Even in preparations of tissue thoroughly infested for some days, in which the spores have burst through the epidermis, the protoplast may retain its organization intact and appear entirely normal. At no stage of the disease is there an extensive killing of the host tissue. As remarked by Marshall Ward, "A uredine, when flourishing in a leaf, does not act as a devastating parasite, but as one which slowly taxes its host, and even stimulates the cells for some time to greater activity."

Infection of a Resistant Host

On Kanred, a wheat variety which, on the basis laid down in Part I of this paper (see Table II), is described as immune to Form XVII, the spores of this form germinate quite normally. The long germ tubes follow the surface of the epidermis, dipping into depressions, in the same manner as was observed in Marquis. On reaching a stoma the tip of the germ tube swells to form an appressorium, and practically all of the protoplasm flows into it, leaving the germ tube almost empty (Plate VI, 3). Often the appressoria formed by two or three spores may be found crowded together at a single stoma (Plate VI, 4).

In spite of this, it appears that in many cases the germ tube fails to get right through the stoma. It forms an appressorium and there stops (Plate VI, 5). Out of many hundreds of sections examined it was possible in 50 or more to observe satisfactorily the relation of the appressoria to the stomata. The formation of sub-stomatal vesicles was observed in only about one-third of these cases. Since, however, the technical difficulty associated with the detection of these vesicles is much greater than in the case of the appressoria, it is possible that a larger proportion of the latter may have made good their penetration. Further, it is not to be supposed that all the appressoria make good their entrance even into a susceptible wheat. In the course of her work the author has frequently observed sections of the susceptible Marquis variety, in which appressoria had apparently failed to get through the stomata.

As previously noted, Miss Allen (1) was of the opinion that only a few appressoria of the rust form with which she worked, a form to which Kanred was highly resistant, succeeded in penetrating the stomata of this variety, and suggested that this may have been due to the narrow stomatal openings. If this observation be correct, it would seem that the very heavy infection of Kanred by such forms as III, XI, XII, XV, XVIII and XXXII, reported in the early part of this paper, could only be explained on the assumption that these forms have smaller germ tubes. The present writer measured the average diameter of the germ tubes produced by spores of Form

XVIII, a form attacking Kanred heavily, and XVII, a form to which it is very resistant, and could find no appreciable difference between the two. Embedded material of Kanred, infected with Form XVIII, to which it is very susceptible, is now on hand, and with this it is hoped to determine the approximate proportion of cases in which the appressoria make good their entry in these circumstances.

It should be added here that preliminary experiments with Mindum (the susceptible variety used by Miss Allen) brought to view cases in which the growing germ tubes passed directly over stomata without forming appressoria (Plate VI, 1 and 2). This, together with the tendency already noted for the fungus to develop appressorium-like bodies in places other than over a stomata (Plate IV, 7), appears to support the view that chemotropic attraction is not a factor in rust infection.

As noted above, in at least a considerable proportion of cases, the germ tube may develop in a resistant host the usual sub-stomatal swelling or vesicle. The latter sometimes fails to send out infection threads. It merely remains beneath the stomatal slit and becomes vacuolated (Plate VI, 6). However, the number of such cases observed was not sufficient to justify any assumption that this condition is more characteristic of resistant than of susceptible varieties. In most cases one or more hyphae are sent out. These hyphae may grow until they meet with a cell, where, at the point of contact, they form a swelling (Plate VI, 7 and 8), and apparently cease growth. In no case were they found to send haustoria into the host cells. The length of time that these hyphae remain capable of growth varies. In some three-day preparations the hyphae were already dead and shrivelled; in no leaves six days after inoculation could hyphae be found which had not obviously reached the end of their capacity for growth.

From the beginning of growth in the host, it is easily discernible that the vigour of the hyphae is not nearly as great as in the case of those growing in the susceptible Marquis wheat. The nuclei of the hyphae become smaller and appear to degenerate, and the whole contents become highly granular and stain deeply. Abnormal symptoms are prompt to appear also in the host cells. Those in the vicinity of the fungus take on a shrunken appearance, and the nucleus and chloro plastids show definite signs of disintegration (Plate VI, 7 and 8). The contest between host and parasite is short and decisive, only a very few host cells being killed. The hyphae seldom develop sufficiently to give any external evidence that the germ tube has even entered.

From the foregoing description it is apparent that infection is a much more complicated matter than the mere entry of the stoma by the germ tube. Up to this point, the development of the fungus follows the same course on either a resistant or susceptible host. In a susceptible (tolerant) host the fungus may then continue its growth and complete its cycle with the formation of a new uredinium, all without any apparent inconvenience to the host. In this case, apparent damage only results when the points of infection become so numerous that the host begins to feel the drain on its supply of nutriment. On the other hand, a resistant (intolerant) host may admit the fungus through its stomatal openings, as has been shown, but quickly checks its further progress. The most reasonable explanation for the failure of the infection in this case appears to be the starvation of the parasite by the local killing of the intolerant host tissue. It is true that the host cells and the parasitic hyphae appear to die so nearly simultaneously as to make it difficult in some cases to decide which perish first. Nevertheless, the author has found in most cases some indication of disintegration in the host cells before a similar break-down could be observed in the hyphae. This is illustrated in Plate VI, 7 and 8.

"To whatever the resistance may be due in the last analysis it seems to be a peculiar, delicately balanced condition of the host against specific parasites, a balance which is not maintained in the same way towards any two species or varieties" (Freeman and Johnson).

Summary of Part II

1. The fungus enters through the stomata of both resistant and susceptible hosts in the same way.

2. The susceptible host seems to adjust itself readily to the presence of the fungus, and the latter develops luxuriantly to the completion of its uredinial cycle.

3. The tissues of a resistant host appear to be intolerant of the fungus. The hyphae sent out by the sub-stomatal vesicles soon perish. It is suggested that the failure of the infection may be due to the starvation of the parasite by the local killing of the host cells.

4. A recent suggestion by Miss Allen that the resistance of Kanred may be due to the narrow stomatal openings of this variety is not supported.

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Explanation of Plates

PLATE I

A Group of Differential Hosts Inoculated With:

A. Form XVII.
B. Form XVIII.
Compare:

Kanred { A. Resistant. B. Susceptible.

Arnautka, Mindum, Speltz Marz { A. Susceptible. B. Resistant.

Other minor differences are not distinguished clearly in the photograph.

PLATE II

Leaves of Little Club

A very susceptible variety, showing normal appearance and size of the uredinia when inoculated with any one of the 14 biologic forms isolated.

Leaves of Khapli (×2 1/2)

The only variety resistant to all the forms isolated.
a and *b*. Small uredinia on dead areas.
c. Minute areas of killed leaf tissue, where no uredinia were formed.

PLATE III

Leaves of Three Grass Species Inoculated with Form XVII

A. Bromus carinatus H and A—Resistant. Note chlorotic areas.
B. Bromus villosus Forsk—Resistant. Note chlorotic areas.
C. Agropyron tenerum Vasey—Very susceptible. Uredinia large and well formed.

PLATE IV

Development of Puccinia Graminis Tritici within the Tissues of a Susceptible Host (Marquis Wheat)

All the drawings in this and succeeding plates were made with a camera lucida.

5. Transverse section of leaf showing the urediniospore germ tube with appressorium, and the passage of the germ tube through the stoma.
6. Longitudinal section of leaf showing an appressorium formed above a stoma.
7. The formation of a swelling or appressorium at some distance from a stoma.
8. The entry of the germ tube and the formation of the sub-stomatal vesicle.
9. The infecting hyphae striking across the sub-stomatal space to branch between the cells.

10. The infecting hypha growing beneath the epidermal cells and sending a haustorium into one of these cells.

11. The formation of an appressorium above a stoma, the germ tube continuing to grow without entering the stoma.

PLATE V

Development of Puccinia Graminis Tritici within the Tissues of a Susceptible Host (Marquis Wheat)

(Continued from Plate IV).

12, 13, 14. Hyphae sending haustoria into the host cells.

15. A host cell containing two haustoria, one of which is clasping the cell nucleus (nuc).

16. Longitudinal section of a leaf showing the distributive hyphae running between the cells.

17. Mycelium branching between the host cells, one fungus cell showing three nuclei.

18. Hyphae running beneath the epidermal cells.

PLATE VI

Development of *Puccinia graminis tritici* (Form XVII) on Mindum, a Susceptible Host (1, 2) and on Kanred, a Resistant Host (3 to 8)

1 and 2. Surface view of Mindum (very susceptible) showing germ tubes passing near to or directly over stomata without entering.

3. Surface view of Kanred (very resistant). Urediniospore germinating and forming appressorium over stoma.

4. Appressoria formed by 3 spores crowded together at a single stoma.

5. Longitudinal section of leaf showing appressorium above stoma. Appressoria frequently fail to penetrate stomatal slit with peg-like process to form sub-stomatal vesicle.

6. Sub-stomatal vesicle.

7. Six days after inoculation. Part of sub-stomatal vesicle still visible. Infecting hypha and host cell disintegrating, the former having died apparently almost as soon as the latter. Hypha granular and without nuclei.

8. Six days after inoculation. Both appressorium and sub-stomatal vesicle still visible. Nucleus of hypha still clearly seen. Protoplast shrunken and rapidly disintegrating.

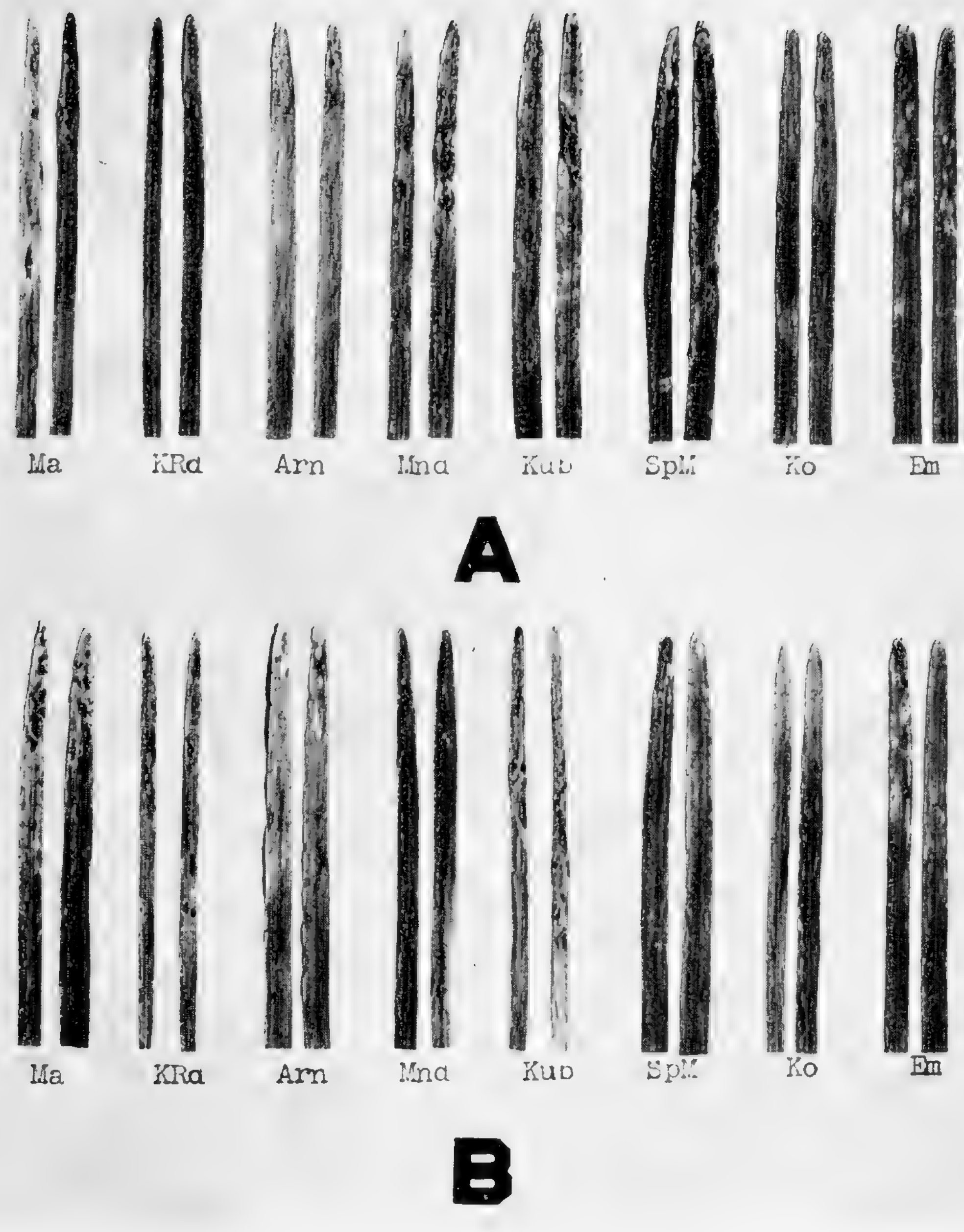


Plate I

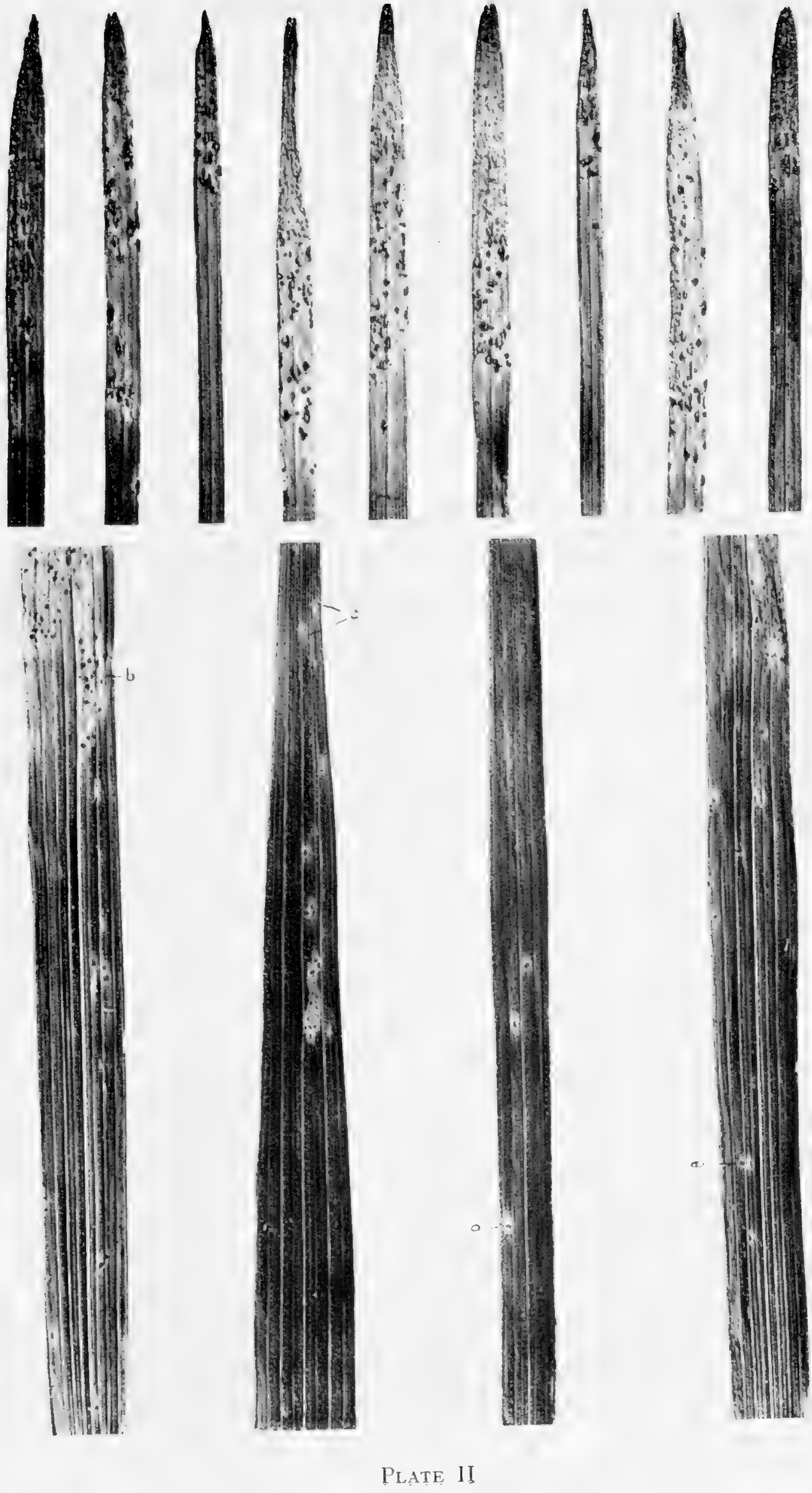


PLATE II

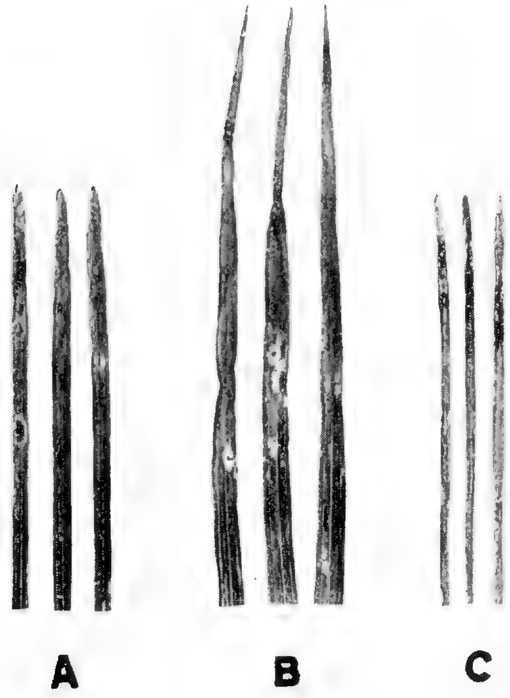


PLATE III

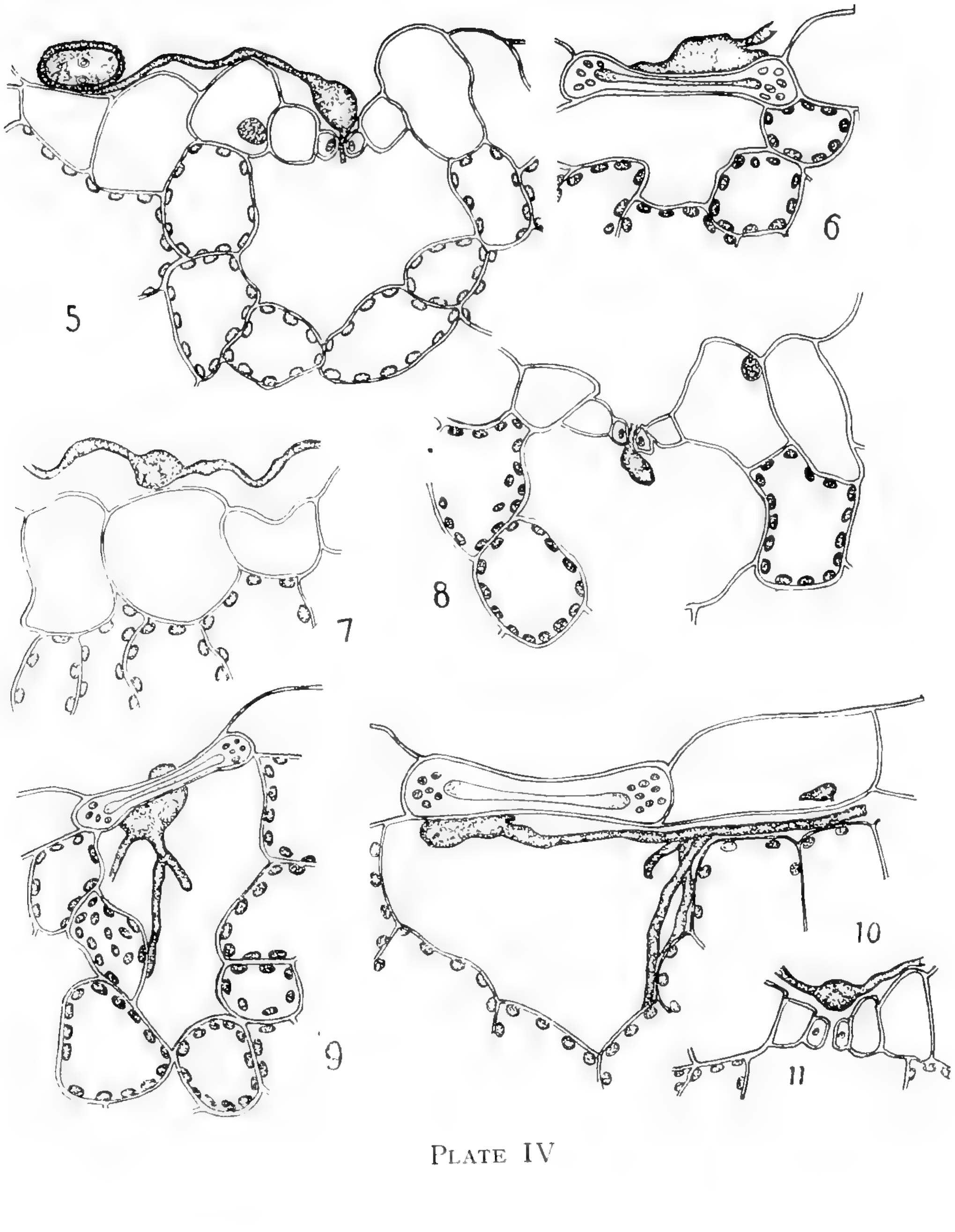


PLATE IV

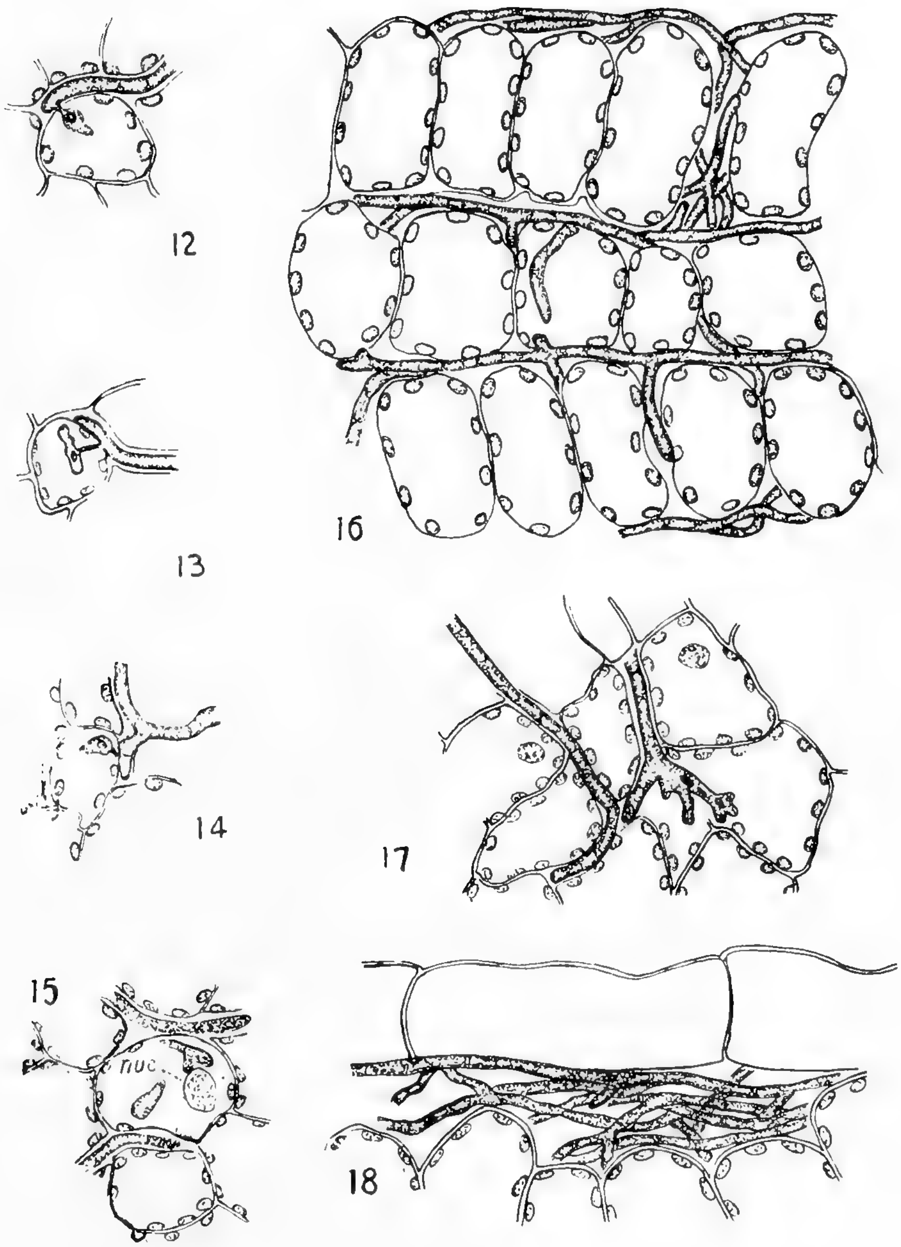


PLATE V

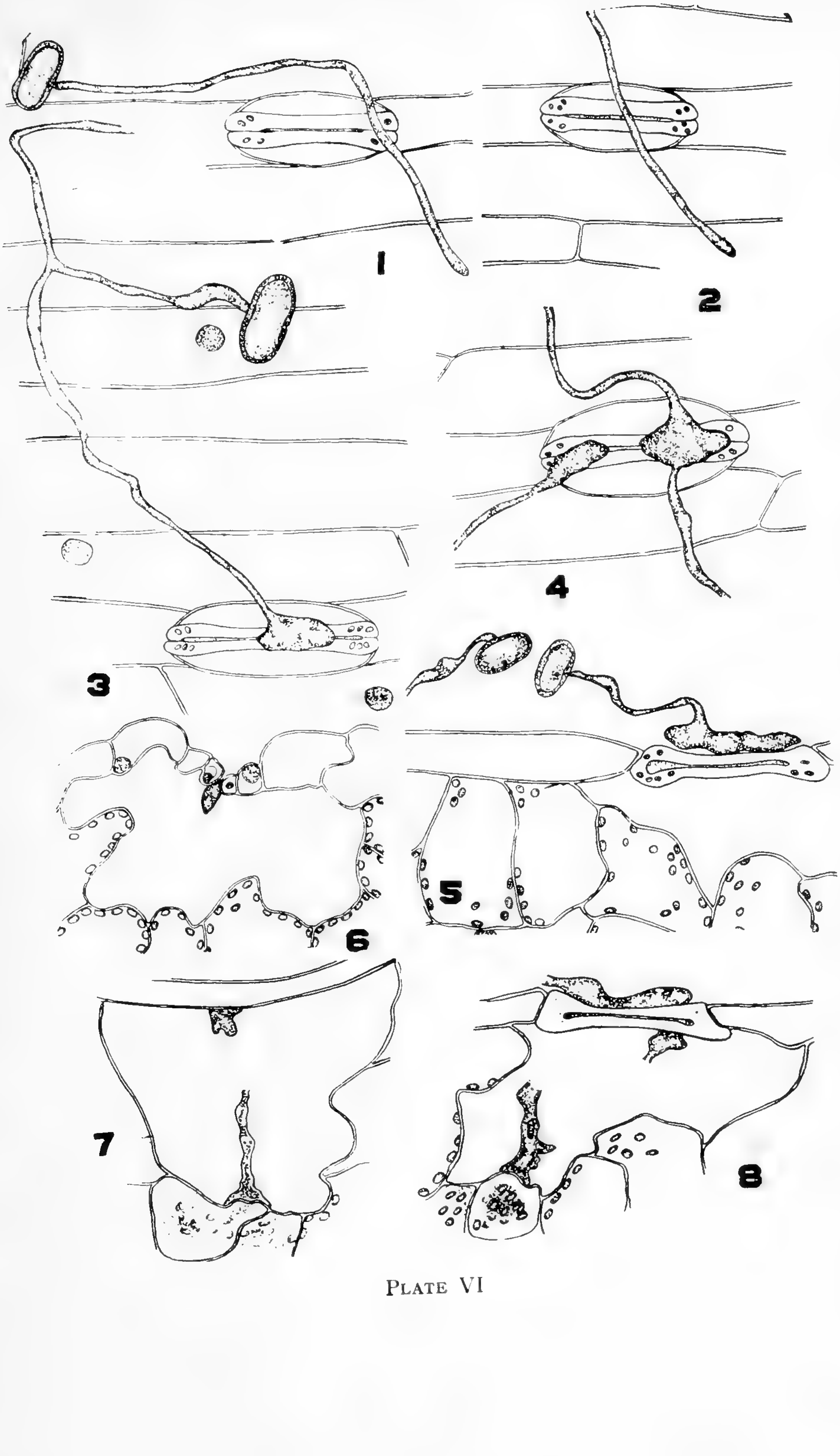


PLATE VI

XVIII. *The Ascidian Family Caesiridae*

By A. G. HUNTSMAN, B.A., F.R.S.C.

(Read May Meeting, 1922)

The Caesirids [Molgulids], like so many other systematic groups, are in need of a revision which will indicate relationships not only of the genera, but of all the other classificatory divisions. The genus *Molgula*, in particular, has come to include so many species that the identification of a species without any delimitation of sub-genera has become a matter of considerable difficulty. Postponement of attempts to classify the species further only increases the confusion, since the descriptions of new species are practically certain to be in most cases insufficient for subsequent assignment to sub-groups. We desire to contribute toward the classification of this family, considering principally those forms which we have had occasion to study.

Nomenclature

The International Rules of Zoological Nomenclature are the result of a careful attempt by an International Committee of zoologists to put nomenclature on a fundamentally just basis. The Rules have received the approval of the International Congress. There is, consequently, no more generally accepted guide for proper usage in the naming of animals. The outstanding object in the formulation of the rules has been to attain uniformity and stability. We believe that this object will be achieved only by a strict adherence to the rules unless and until they are changed or abrogated in special instances by such general consent as approval by an international congress. For these reasons we do not propose to adopt the arbitrary list of "Ascidiarum nomina conservanda" prepared by Hartmeyer in consultation with Michaelsen and Sluiter.

Parallelism and phylogeny

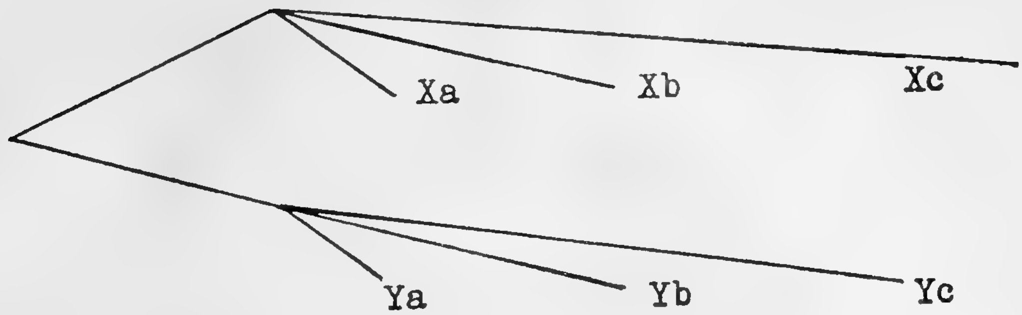
In the recent past the general aim of systematists has been to produce a genetic classification, that is one which would correspond with the evolutionary history of the group under consideration. It has been taken as axiomatic that relationship proves community of origin. In the inorganic world we do not hold to this view. It is a commonplace that substances to all intents and purposes identical with each other arise quite independently of each other, and widely separated in space and time. Not only so, but these substances which are indistinguishable from each other may originate in widely dissimilar fashion. The same has been shown to hold true for organic substances, as witness the numerous ways in which urea can be synthesized from inorganic sources as well as in living organisms.

Apparently the only good reason for believing that this is not also true of organisms themselves is that they are comparatively so complex and so rare. The more complex a kind of thing is, and the less frequently it occurs, the more reasonable it is to suppose that the conditions necessary to produce it have obtained only once, and that consequently all of that kind are connected in origin.

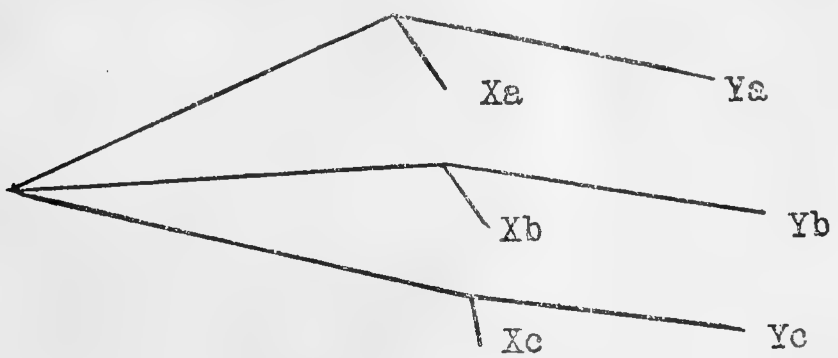
Are we altogether justified in making this supposition? As to the actual origin of entirely new forms we have not yet the necessary knowledge to state that a certain new form has arisen repeatedly at different times and places. In the origin of new forms by the crossing of common species, we are able to affirm that the same kind has been produced on many occasions, and the study of genetics has shown us how these new kinds can be produced at will.

In systematic study there has arisen a large body of facts that supports strongly the view that the same species has arisen repeatedly and even by different paths. When almost identically the same form occurs at places remote from each other, those who are committed to the view that a species has been produced but once, predicate as a matter of course some transference of the species from one place to the other, and in this they are justified, for the spreading of a species is a phenomenon readily demonstrable, and frequently observed, whereas the production of a new species has so far been a doubtful thing.

However, the phenomena of parallelism afford cases that admit of no other interpretation than that frequently the same evolutionary process has been repeated. Examples of intergeneric parallelism are not infrequent among Ascidians as well as in other groups of animals, and a hypothetical case may be used as an illustration. In two closely allied genera, X and Y, there are parallel series of species, Xa, Xb and Xc, and Ya, Yb and Yc, where Xa and Ya are similar except in generic characters, and the same for the other pairs Xb and Yb, Xc and Yc. If the classification correctly interprets the phylogeny or origin of these forms, the following arrangement would approximate their ancestral history.



Cope (1868, p. 272) was led to consider it possible that "one and the same species (if origin be the definition), has, in the natural succession, existed in more than one genus." With such a conception the classification would not be expected to show the natural succsesion, which might in the above case be as follows.



In each of these arrangements parallel evolution is well shown. In the former case there is the independent production of the corresponding a, b and c species in the two genera, and in the latter case the independent production of the X and Y generic characters in the a, b and c lines of evolution. It is quite conceivable that both methods of evolution have been followed, and that the species Yb has been produced in two different ways, namely, by acquiring the generic characters (Y) first and the specific characters (b) later, as in the first scheme shown above; and by acquiring the specific characters (b) first and the generic characters (Y) later, as in the second scheme. The Mendelian phenomena of genetic segregation indicate that, if this did occur, the final products in the two cases might be indistinguishable.

As the facts of parallelism prove that nearly related groups of species have passed through almost identical evolutionary processes in many instances, it is only reasonable to suppose that groups of individuals all belonging to the same species still more frequently evolve along the same paths. If this evolution be of the nature of the production of two or more kinds from one, for example a_1 producing b_1 and c_1, and a_2 producing b_2 and c_2, we have as a result that the dissimilar forms b_1 and c_1, or b_2 and c_2 are more closely related than are the similar forms b_1 and b_2, or c_1 and c_2. Also there is the possibility of the same form being produced in two different ways as indicated above for Yb. From these considerations it seems very doubtful whether our ultimate aim in classification should be a phylogenetic arrangement, or not.

The Unit in Classification

The unit which we use in classification is the species, a thing that admittedly is not capable of very exact definition. In describing a species we consider those characters to be irrelevant that can be shown to have resulted from unusual conditions during the development of the individual, that is, we definitely exclude differences that are purely environmental. In our description of a species we feel free to include not only the characters of the adult, but also those of any or all stages from one generation to the next. It is evident from what we exclude and from what we include that we are attempting to describe the heritable part of a more or less homogeneous group of individuals. The only part that is heritable, that is, that is transmitted from one generation to the next, is the germ plasm, and consequently that it is that we are attempting to classify. We deduce the nature or structure of this apparently simple, but really complex thing, the germ plasm, from what it produces under certain standard or natural conditions, namely from the characters of the adult and of the various developmental stages leading to the adult. We are forced to use these very indirect means of determining the properties or nature of the germ-plasm, for we have not yet been able to determine its distinctive properties directly.

Our position in regard to organic species is similar to, but not so good as, that in regard to chemical elements. We know the properties of the chemical elements not only indirectly from what they produce under definite conditions, namely, from their compounds, but also directly from the characteristic properties of the elements themselves and to such a degree that a theory of their structure is being worked out. For both species and elements we deduce theoretical evolutionary series from a simple to a complex condition, without yet having been able either to observe in nature or to produce experimentally a single transformation in the series.

At the present time we classify germ plasms on the basis of their properties determined indirectly. We may look forward to having at some time in the future a knowledge of their structure as a basis for classification. Such knowledge will be the outcome of analysis or synthesis of the germ plasms. While there is no immediate prospect of our being able to analyse and synthesize these in the direct chemical fashion, there is already well under way an indirect analysis and synthesis of germ plasms, namely, in the elucidation of the Mendelian phenomena. When work in this comparatively new field shall have become sufficiently extensive it will provide the foundation for a much better system of classification.

Early History of the Family

Baster (1760) appears to have been the first author to describe a member of this family, and, believing his animal, which was found on the coast of Holland, to be new, he gave it the name *Ascidium*. This was adopted by Linnaeus in the 12th edition of his *Systema Naturae*, under the altered spelling *Ascidia*, as the name for all the sea-squirts which he knew. Later, when the group of sea-squirts was subdivided, the name with variable spelling came into general use for the whole group, as (in English) *Ascidians*.

Baster's species has not been recognized since his time. It was probably the same form as described in 1846 by P. J. van Beneden under the name *Ascidia ampulloides*. If this can be determined there seems no good reason why Baster's name *Ascidium* should not come into use for the group of species that includes *A. ampulloides*.

Pallas in 1776 and 1787 described an *Ascidia globularis* from the Kara sea. We have shown that this belongs to the genus *Rhizomolgula*, instituted by Ritter in 1901 for specimens from Alaska, and it now appears that there is just the one species of this genus, which was not rediscovered until more than a century had elapsed. In the last twenty years its distribution has been quite well worked out.

In 1816 Savigny described from the Red Sea a species of Ascidian which he named *Dione*, which he placed in a new genus *Cynthia*, and for which he made a special tribe, the *Cynthiae Coesirae*. In 1822 Fleming erected this tribe into a genus, using the name *Caesira* and indicating Savigny's species as the type. Until Baster's form is cleared up, the genus *Caesira* is to be considered the oldest in the family, and hence gives its name to the latter.

In 1825 MacLeay described the new genus and species *Cystingia griffithsii* from material obtained in the Canadian arctic. This has been of doubtful systematic position until recently, when we (Huntsman, 1922) showed it to be identical with the *Clavelina chrystallina* of Möller (1842), which was obtained at Greenland. *Cystingia* is, therefore, the second named genus in this family.

In 1834 Quoy et Gaimard described the species *Ascidia tumulus*, obtained at Australia. It was described in detail by Pizon in 1898. Hartmeyer (1914, p. 3) has called attention to the fact that Gervais in 1840 instituted the genus *Syphonotethis* for this species.

In 1848 Forbes formed the genus *Molgula* for the species *M. oculata* and *M. tubulosa*. This genus was the first genus of the family to be generally adopted and recognized by systematists, and, when the family was separated by Lacaze-Duthiers in 1877, it was considered the oldest genus, and the family was accordingly called the *Molgulidae*, by which name it has gone until quite recently.

Since the middle of the last century there has been a steadily increasing number of species and genera added to this family.

The Classification

The current classification of this family is particularly unsatisfactory as it lacks any sub-division of the heterogeneous genus *Caesira* or *Molgula*. The history of the family has largely been a continued separation of small genera from the old, comprehensive genus *Molgula*. Many of the new groups proposed have not met with general acceptance, so that *Molgula* has become to an increasing extent an unsatisfactory assemblage of diverse species.

Giard in 1872 proposed the genera *Gymnocystis* and *Lithonephrya*, neither of which have been recently recognized. In founding the family in 1877 Lacaze-Duthiers instituted the genera *Anurella* and *Ctenicella*, of which the latter alone has gained any currency. Pizon in 1898 and 1899 introduced the genera *Gamaster*, *Astropera*, *Stomatropa*, and *Meristocarpus*, of which only the first has been accepted. In more recent times we have Seeliger's (1907) *Molgulidium* and *Eugyrioides*, and Hartmeyer's (1914) *Pareugyrioides* and *Molgulina*. Of these four the second and third appear sufficiently well characterized to be valid. No matter what classification proves best there is at our disposal a considerable number of generic names for use in accordance with the International Rules of Nomenclature. In the classification that we propose, these will be used wherever available, but with frequent alteration of diagnosis and scope.

The importance of any group of characters for classificatory purposes varies in inverse ration with their variability and the extent of their intergrading. Nevertheless, it cannot be expected that a character distinguishing a classificatory division, no mattter how high the grade of the latter may be, shall be absolutely constant and invariable in that division, and shall absolutely fail to intergrade with the opposed character distinguishing a neighbouring division. A division into groups should not be condemned merely on account of intergrading in the characters used in making the division, although it is much better if clearly cut distinctions between natural groups can be shown. The important thing is to define groups that are natural. We may objectively define a natural group as one containing units of a lower grade which can be shown to be similar on the basis of as many and as invariable characters as possible. It is important, therefore, to consider as many characters or systems as possible in an attempt to produce a natural classification.

The principal characters that have been used for distinguishing genera in this family are the following: presence or absence of definite pharyngeal folds, number of folds, arrangement of stigmata, condition of siphonal lobes, position of intestinal canal, number and distribution of gonads. The only features to which sufficient attention seems not to have been paid, and which we wish to emphasize, are the structure, orientation and situation of the gonads. In structure, the chief differences consist in the extent to which the testicular portion is separated from the ovarial part in each gonad, and in the arrangement of the testicular lobes in relation to the ovary. At one extreme, the testicular lobes are closely massed around the ovary, and almost enclose the latter, leaving only parts of the inner and outer surfaces free, and the efferent ducts unite into a common vas deferens, which is closely applied to the oviduct, the two opening together. At the other extreme, the testicular lobes are more or less distinct from the ovary, and are divided into groups, each with its own vas deferens opening separately into the atrial cavity. In orientation, we have in one small group of species, the gonad reversed from the usual condition and opening at its anterior end instead of its posterior. The situation of the gonad varies considerably on the left side and in relation to the intestinal loop, being either in the latter or above it. In the latter case it may be more or less enclosed by a secondary bending of the intestinal loop around it, or it may be above such secondary bending. A new and clearer order is apparent if we take into account these gonadic characters, and we, therefore, propose to make them the basis of the main divisions in the family, indicating at the same time how they are reinforced by other characters.

No matter what basis we use for classification in this family we are confronted with a considerable amount of parallelism. Neighbouring sub-families or genera show similar series of genera or species respectively. This makes classification doubly hard, as it permits of alternative very diverse and, at first glance, equally natural schemes. In the past the characters presented by the pharynx have been considered as of major importance in Ascidian classification. This is owing to the diversity of structure exhibited by this organ as well as to the ease with which this structure may be observed. We believe, nevertheless, that in the classification of this family the characters presented by the pharynx are of minor importance to those presented by the gonads. The fact that the pharyngeal characters used for distinguishing the genera are to a considerable extent such as alter from one type to another during the development of the individual makes them on the whole more variable than the gonadic characters. The latter, also, seem to be more fundamental, that is, related to the structure of the germ-plasm. The reason for this may be that the distinctness of such systematic groups as we are here dealing with depends upon the inability of the eggs and sperms of any two groups to unite, that is, crossing of species or genera whose eggs and sperms are mixed promiscuously in the sea water may depend upon certain peculiarities in the structure of these eggs and sperms. If differences in the structure of the gonads exist, these may well be correlated with differences in the structure of the eggs and sperms that are produced in these gonads.

Seeing that so little attention has in the past been given to the structure of the gonads in connection with classification, it is not surprising that most of the species in this family have not been described fully enough as regards the gonads for one to be altogether certain, or even in many cases to have any idea of, their position in the present scheme of classification, and comparatively few species have been available to us for examination. Many species, and even several genera, have consequently not been brought into the scheme. Further knowledge concerning these is much to be desired, and will make it possible to fill the gaps and correct the mistakes in this classification. In a number of cases, where there has not been sufficient information, a genus or species has been assigned a position on the basis of its structure so far as known.

Synopsis of Genera

A_1. Left ovary in or across intestinal loop, with usually several distinct testicular systems grouped along it. Vasa deferentia not passing along inner surface and lengthwise of ovary. (*Eugyrinae*).

B_1. A gonad on each side of body.

C_1. Pharynx with nine folds on each side. *Halomolgula.*

C_2. Pharynx with seven folds on each side. *Molguloides*, gen. nov.

C_3. Pharynx with five folds on each side. *Ectorchis*, gen. nov.

C_4. Pharynx with from 5-7 long. bars on each side instead of folds. *Eugyrioides.*

B_2. A gonad on the left side only.

D_1. Pharynx with six folds on each side. *Rhizomolgula.*

D_2. Pharynx with from 6 to 9 long. bars on each side instead of folds. *Eugyra.*

A_2. Left ovary above intestinal loop. Testicular lobes either arranged alongside the more or less elongated ovary, or else somewhat definitely separated from it and in masses. (*Cystingiinae*).

E_1. Testicular lobes arranged along and to a considerable extent on the outer side of ovary. Vasa deferentia attached to mantle (body-wall), running parallel to oviduct, and opening near latter. (Pharynx with seven longitudinal bars on each side in place of folds). *Paramolgula.*

E_2. Testicular lobes bordering and more or less enclosing ovary. Vas deferens single and running along middle of inner surface of ovary to open near oviduct.

F_1. Pharynx with seven folds on each side. *Anurella.*

F_2. Pharnyx with six folds on each side. *Euritteria*, gen. nov.

E_3. Testicular lobes bordering and more or less enclosing ovary. Vasa deferentia opening on inner surface of gonad and not running parallel to ovary.

G_1. A single gonad, situated on the left side. *Eugyriopsis.*

G_2. A gonad on each side of the body.

H_1. Pharynx with seven folds on each side. *Molgula.*

H_2. Pharynx with six folds on each side. *Gymnocystis.*

E_4. Testicular lobes more or less separated from ovary and in distinct masses. Vasa deferentia short and not related to ovary.

I_1. Pharynx with from five to seven folds on each side. *Cystingia.*

I_2. Pharynx with seven longitudinal bars on each side in place of folds. *Pareugyrioides.*

A_3. Left ovary (if present), above intestinal loop. Testicular lobes massed at blind end of ovary and radially arranged. (*Caesirinae*).

J_1. A gonad on each side of body.

K_1. A single vas deferens, passing along inner side of ovary and opening near oviduct. *Syphonotethis.*

K_2. Vas deferens or vasa deferentia opening into atrial cavity near blind end of ovary, that is, not accompanying the latter.

L_1. Pharynx with folds.

M_1. Oviduct directed toward atrial aperture. *Caesira.*

M_2. Oviduct directed anteriorly, that is, away from atrial aperture. *Lithonephrya.*

L_2. Pharynx without folds.

N_1. Stigmata present. *Oligotrema.*

N_2. Stigmata absent. *Hexacrobylus.*

J_2. A single gonad, situated on the right side. *Gamaster.*

In order not to burden the present article unduly we have neither indicated the synonymy of the various species, nor given references to the original descriptions, except in a few cases. Practically all the references not given can be found in Hartmeyer's account of the family in Bronn's Tierreich, Bd. III, Suppl. pp., 1316-1329, to which the reader is referred.

Species which we have personally been able to examine for this study are indicated with an asterisk (*).

EUGYRINAE sub-fam. nov.

This sub-family shows a very general tendency for the stigmata that form the infundibula not to become sub-divided as development proceeds. This is well shown in the genus *Eugyra* and is responsible for the name. In *Rhizomolgula*, *Ectorchis*, and *Molguloides* more or less subdivision occurs. In *Halomolgula*, which is doubtfully assigned to this group, subdivision has been carried to an extreme.

In two of the genera (*Eugyra* and *Eugyrioides*), representing different sub-groups, the pharyngeal folds fail to develop into the condition characteristic of the family, the post-larval condition of a single longitudinal bar for each row of stigmatic coils remaining throughout life.

The dorsal tubercle remains for the most part very simple, in many cases not showing more than a simple funnel-shaped aperture. Where the aperture becomes slit-like and bent it takes the form of a simple horse-shoe with the opening between the horns usually directed anteriorly or to the left.

The chief character of the sub-family is the position of the left gonad, which is in or placed across the primary intestinal loop. In addition there are usually several testicular systems for each gonad, and the vasa deferentia are for the most short and open separately into the atrial cavity, not passing along the inner surface of the ovary to open near the oviduct.

HALOMOLGULA Ritter

Pharynx with nine well-developed folds on each side. Infundibula extending into folds, each having numerous short stigmata. Dorsal lamina with crenulated margin. Dorsal tubercle a simple opening.

A gonad on each side, the left in the intestinal loop. Testicular lobes bordering the ovary. Number and course of vasa deferentia not known.

Type and single species.—*H. ovoidia* Ritter.

Ritter established this genus largely because of there being calcareous spicules in processes of the test. The position of this genus in our system is somewhat doubtful, but it would seem to belong near *Molguloides.*

MOLGULOIDES gen. nov.

Syn. *Molgula* et *Caesira* auct. (partim).

(Molgula and εἶδος, appearance).

Pharynx with seven folds on each side. Infundibula extending into folds, each having a number of rather short stigmata. Dorsal lamina with smooth margin. Dorsal tubercle simple, or horse-shoe shaped with opening between horns directed to left.

A gonad on each side, the left in the intestinal loop. Testicular lobes bordering and more or less enclosing ovary. Several vasa deferentia, not accompanying oviduct.

Type species—*M. vitrea* (Sluiter) as described by Van Name, 1918, p. 68.

Molgula sordida Sluiter, *M. vannamei* Oka (1914, p. 452) and *M. japonica* Hartmeyer probably belong here, but they are as yet insufficiently described.

ECTORCHIS gen. nov.

Syn. *Molgula* et *Caesira* auct. (partim).

(ἐκτός and ὄρχις, in allusion to the external position of the male part of the gonad)

Pharynx with 5 folds on each side. Infundibula extending into folds, each having many stigmata spirally arranged. Dorsal lamina with smooth margin. Dorsal tubercle with aperture horseshoe shaped, the horns inrolled, and the opening between directed forwards.

A gonad on each side, the left placed across the intestinal loop on its inner side. Testicular lobes in a large flat mass against mantle and (on left side) intestinal loop, and outside blind end of ovary. Vas deferens attached to mantle and passing along and beyond open or atrial end of ovary.

Type and single species—*E. hupferi* (Michaelsen).

The systematic position of this form is doubtful. In the relations of the testis and vas deferens (on the outer side of the ovary) it resembles *Paramolgula*. The relation of the gonad to the intestine is similar to that in some species of *Eugyra*, and the stalk with special muscles resembles the "root" of *Rhizomolgula*.

EUGYRIOIDES Seeliger

Pharynx with from 5 to 7 longitudinal bars on each side in place of folds. Infundibula in rows corresponding to the bars, each consisting of two long spirally coiled stigmata. Dorsal lamina with smooth margin. Dorsal tubercle a simple opening.

A gonad on each side, the left in the intestinal loop. Testicular lobes bordering and more or less enclosing ovary. Several vasa deferentia not accompanying oviduct.

Type species—**E. glutinans* (Möller). Another species is *E. schmidti* Redikorzew (1914, p. 42). *E. guttula* (Michaelsen), *E. molguloides* (Sluiter), and *E. symetrica* (Drasche) have been assigned to this genus, but the structure of the gonads is not sufficiently known for their systematic position to be determined. *Paramolgula arctica* Bonnevie has also been placed in this genus, but the author states that the left gonad is in front of the intestinal loop, which would make it necessary to place it elsewhere. It cannot be accurately assigned until the structure of its gonads is known.

RHIZOMOLGULA Ritter

Pharynx with six folds on each side. Large infundibula in folds and small accessory ones between folds. Stigmata varying in size, and arranged spirally in the infundibula. Dorsal tubercle with opening between horns directed anteriorly and to left. Dorsal lamina with smooth margin.

Single gonad, situated on the left side, in the intestinal loop. Testicular lobes, bordering and more or less enclosing ovary. Several vasa deferentia, not accompanying oviduct.

Type and single species—**R. globularis* (Pallas) (see Huntsman, 1913, p. 137).

EUGYRA Ald. and Hanc.

Pharynx with from 6 to 9 longitudinal bars on each side in place of folds. Infundibula consisting of one or two spirally coiled stigmata, little or not at all divided. Dorsal lamina with smooth edge. Dorsal tubercle a simple opening, or horse-shoe shaped with opening between horns directed to right or left.

Single gonad, situated on the left side and in or across the inner side of the intestinal loop. Testicular lobes bordering and more or less enclosing ovary. One to several vasa deferentia, not accompanying oviduct.

Type species—*E. arenosa* Ald. and Hanc.

Sub-gen. *Eugyra*

Type—*E. arenosa* Ald. and Hanc.

Infundibula large and in rows corresponding to the longitudinal bars.

In addition to the type, there are *E. adriatica* Drasche, *E. pedunculata* Traust., *E. translucida* Kiaer, and probably *E. bilabiata* Sluiter. We have examined a species from the California coast. *E. kerguelenensis* Herdman probably does not belong in this genus. While Herdman (1882, p. 81) gives the generic characters to include the presence of only a single gonad placed on the left side, he has figured for two specimens of this species (Pl. VI, Figs. 4 and 5) what appears to be a gonad on the right side.

Sub-gen. *Bostrichobranchus* Traustedt

Syn. *Herdmania* Metcalfe

Type and single species—*E. pilularis* (Verrill).

Infundibula in adult small, numerous, and irregularly arranged.

CYSTINGIINAE sub-fam. nov.

The stigmata in this sub-family are characteristically variable in length, more or less bent, and arranged rather definitely in a spiral fashion around the infundibula. They do not seem ever to fail to divide and so to form a continuous spiral as in many of the *Eugyrinae*, nor are they subdivided in that regular fashion that produces rows of stigmata transverse to the folds as in the typical *Caesirinae*.

In only two genera (*Paramolgula* and *Pareugyrioides*) do the folds of the pharynx remain in that simple post-larval condition of being represented by single longitudinal bars.

Dorsal tubercle usually well developed, the horns of the slit-like aperture being coiled in the opposite sense, that is, toward each other on the same side (the usual condition in Ascidians). The opening between the horns is directed variously, but usually posteriorly or to the right, that is in directions opposite to the usual ones for the *Eugyrinae*.

In several genera a marked tendency is shown for the intestinal loop to be strongly bent upwards to form a secondary loop.

The left gonad is always above the primary intestinal loop, never in or across it as in the *Eugyrinae*. The testicular lobes are variously arranged, but are never arranged radially in a mass situated at the blind end of the ovary as in the *Caesirinae*.

PARAMOLGULA Traustedt

Syn. *Stomatropa* Pizon

Pharynx with 7 longitudinal bars on each side in place of folds. Infundibula irregular in size and arrangement, each having few to many short stigmata spirally arranged. Dorsal lamina with smooth margin. Dorsal tubercle horseshoe-shaped with horns spirally inrolled and opening between directed to right side or anteriorly.

Intestinal loop strongly curved into a secondary loop. A gonad on each side, the left above both primary and secondary intestinal loops. Testicular lobes bordering and more or less enclosing ovary on outer side. One to several vasa deferentia attached to mantle parallel to oviduct, and opening near latter.

Type species—*P. schulzii* Traust.

Other species, which, although not fully described, we can with confidence place in this genus, are *P. chilensis* Hartmeyer (1914, p. 18), *P. filholi* (Pizon), *P. gigantea* (Cunningham), *P. glomerata* (Pizon), *P. gregaria* (Lesson), *P. horrida* (Herdman), *P. lebruni*

(Pizon), *P. patagonica* (Michaelsen), *P. rugosa* (Pizon) and *P. villosa* (Pizon). Among these there are doubtless several synonyms.

This genus occupies a somewhat isolated position. In the peculiar position of the testicular lobes and vasa deferentia it differs from all other genera of the family except *Ectorchis*. The great number and irregular disposition of the infundibula recall the condition in *Bostrichobranchus* and *Rhizomolgula*. Elsewhere in the *Cystingiinae* the development of small infundibula accessory to the principal ones is not unknown, but is not carried so far as in these three genera.

ANURELLA Lacaze-Duthiers (sens. nov.)

Syn. *Molgula* et *Caesira* auct. (partim.)

Pharynx with seven folds on each side. Infundibula extending into folds, each having many stigmata spirally arranged. Dorsal lamina with smooth margin. Dorsal tubercle with aperture horseshoe-shaped, the horns incoiled, and the opening between horns directed posteriorly or to right.

A gonad on each side, the left above and parallel to the intestinal loop. Testicular lobes bordering and more or less enclosing ovary. A single vas deferens accompanying ovary and oviduct.

Type species—*A. bleizi* Lac.-Duth.

The only other species that we can assign to this genus is *A. maxima* (Sluiter).

EURITTERIA gen. nov.

Syn. *Molgula* et *Caesira* auct. (partim)

(Named after Prof. W. E. Ritter, who has contributed so much to our knowledge of Ascidians)

Pharynx with 6 folds on each side. Infundibula extending into folds, each having many stigmata spirally arranged. Dorsal lamina with margin smooth or toothed. Dorsal tubercle with slit-like aperture more or less bent into the shape of a horse-shoe, the horns sometimes spirally coiled. Opening between horns directed variously.

Intestinal loop often strongly curved into a secondary loop. A gonad on each side, the left above primary, but in or else closely applied along secondary intestinal loop. Testicular lobes bordering and more or less enclosing ovary. A single vas deferens, accompanying ovary and usually oviduct also.

Type species—**E. cooperi* (Huntsman, 1913, p. 134).

This genus is conveniently divided into three sub-genera.

Sub-gen. *Euritteria* nov.

Dorsal lamina with smooth margin. Opening between horns of dorsal tubercle directed to left. Intestinal loop little or moderately curved. Left gonad rather closely applied to intestinal loop and extending forward out of secondary loop. Right gonad extending forward beyond renal organ.

Type species—*E. cooperi* (Huntsman, 1913, p. 134).

The only other species is *E. regularis* (Ritter).

Sub-gen. *Comita* nov.

(*Comes*, a companion, in allusion to the course of vas deferens).

Dorsal lamina with margin smooth or nearly so. Dorsal tubercle with opening between horns directed variously, usually to left or anteriorly. Intestinal loop somewhat strongly curved into a secondary loop. Left gonad in secondary loop. Right gonad extending around and below anterior end of renal organ.

Type species—*E. arenata* (Stimpson).

Other species are *E. impura* (Heller), and *E. occidentalis* (Traust.).

Sub-gen. *Euperiptycha* nov.

Dorsal lamina more or less toothed on margin. Dorsal tubercle with opening between horns directed posteriorly or to right. Intestinal loop strongly curved into a secondary loop. Left gonad embraced by secondary loop (περιπτῦχής, embraced). Right gonad entirely above renal organ.

Type species—*E. socialis* (Alder).

Other species are *E. tubifera* (Orsted), *E. dentifera* (van Beneden), *E. greefi* (Michaelsen), and *E. lütkeniana* (Traust.).

EUGYRIOPSIS Roule

Pharynx with seven folds on each side. Infundibula extending into folds, each having many short stigmata spirally arranged. Dorsal lamina with smooth margin. Dorsal tubercle horseshoe-shaped with incurved horns; opening between horns directed backwards and to left.

A single gonad, situated on the left side above the primary intestinal loop. Testicular lobes bordering and more or less enclosing ovary. Several vasa deferentia, not accompanying oviduct.

Type and single species—*E. intermedia* Roule.

MOLGULA Forbes (sens. restr.)

Pharynx with seven folds on each side. Infundibula extending into folds, each having many rather short stigmata spirally arranged. Dorsal lamina with smooth margin. Dorsal tubercle with aperture in form of slit, usually bent into the shape of a horseshoe with the horns incoiled. Opening between the horns usually directed posteriorly or to the right, but occasionally to the left.

Intestinal loop not strongly curved into a secondary loop. A gonad on each side, the left above primary, and in secondary loop, when such is formed. Testicular lobes bordering and more or less enclosing ovary. One to many vasa deferentia, not accompanying ovary and oviduct.

Type species—*M. oculata* Forbes.

Other species are: *M. pannosa* Verrill, *M. roscovita* (Lac.-Duth.), *M. solenota* (Lac.-Duth.), *M. citrina* Ald. and Hanc., *M. septentrionalis* Traust., *M. apoploa* (Huntsman, 1913, p. 129). *M. hecateia* (Huntsman, 1913, p. 130), *M. pugetiensis* Herdman, *M. pacifica* (Huntsman, 1913, p. 132), *M. birulai* Redikorzew, and *M. helleri* Drasche.

M. arctica Kiaer, *M. psammodes* Traust., *M. siphonalis* Sars, *M. römeri* Hartmeyer, *M. aidae* Oka (1914, p. 453), *M. xenophora* Oka (1914, p. 457) and *M. kophameli* Michaelsen probably belong in this genus as restricted in the diagnosis given, but their descriptions are not sufficiently complete.

GYMNOCYSTIS Giard(sens. nov.)

Syn. *Molgula* et *Caesira* auct. (partim)

Pharynx with six folds on each side. Infundibula extending into folds, each having many rather short stigmata, spirally arranged. Dorsal lamina with margin smooth (or rarely toothed). Dorsal tubercle horseshoe-shaped with horns more or less incurved. Opening between horns directed posteriorly or to right.

Intestinal loop strongly curved into a secondary loop. A gonad on each side, the left above primary, and in secondary intestinal loop. Testicular lobes bordering and more or less enclosing ovary. Several vasa deferentia, not accompanying oviduct.

Type species—*G. ampulloides* P. J. Van Beneden.

Other species are *G. euprocta* (Drasche), *G. manhattensis* (DeKay) and *G. simplex* Hancock.

Molgula georgiana Michaelsen, *M. koreni* Traust., *M. platei* Hartmeyer (1914, p. 8), *M. rotunda* Oka (1914, p. 448) and *Caesira robusta* Van Name (1912, p. 505) perhaps belong here.

This genus has much in common with *Molgula*, but differs rather distinctly from the latter in having the intestinal loop strongly curved into a secondary loop, which embraces the left gonad, as well as in having a smaller number of pharyngeal folds. The latter character is remarkably constant. In these same characters it approaches the sub-genus *Euperiptycha* of the genus *Euritteria.*

CYSTINGIA MacLeay

Syn. *Pera* Stimpson.
Meristocarpus Pizon
Molgula et *Caesira* auct. (partim)

Pharynx with from 5 to 7 folds on each side. Infundibula extending into folds, each having many short stigmata spirally arranged. Dorsal lamina with smooth margin. Dorsal tubercle horseshoe-shaped, with horns sometimes incurved and coiled: opening between horns directed to right or posteriorly.

A gonad on each side, the left ovary above the intestinal loop. Testicular lobes irregularly disposed, with from one to many separate testicular systems, partly beside ovary and partly separate from latter, a portion on the left side frequently in the intestinal loop, and on the right side below the renal organ. Vasa deferentia not accompanying oviduct.

Type species—*C. griffithsii* MacLeay. (*Molgula crystallina* auct., see Huntsman, 1922).

In addition to the type species the genus includes *C. retortiformis* (Verrill), and *C. redikorzevi* Oka, (1914, p. 446).

PAREUGYRIOIDES Hartmeyer

Pharynx with 7 longitudinal bars on each side in place of folds. Infundibula in rows corresponding to the bars, each having rather many spirally arranged stigmata. Occasional accessory infundibula. Dorsal lamina with smooth margin. Dorsal tubercle more or less horseshoe-shaped with opening between horns directed to the right.

A gonad on each side, the left ovary above the intestinal loop. Testicular lobes irregularly disposed with many separate testicular systems in several masses, which are partly beside ovary and partly separated, one mass on the left side being in the intestinal loop. Vasa deferentia not accompanying oviduct.

Type species—*P. dalli* (Ritter, 1913, p. 441).

P. japonica Hartmeyer (1914, p. 23) is a second species.

The condition of the testicular lobes is strikingly like that of *Cystingia*, with which genus it is most closely related. In the primitive condition of the pharyngeal folds it resembles such widely different genera as *Eugyra*, *Paramolgula* and *Gamaster.*

CAESIRINAE sub-fam. nov.

In this sub-family there is a general tendency for the apertural lobes, particularly the oral, to be fringed or subdivided. This reaches its extreme in the unusual forms *Oligotrema* and *Hexacrobylus*, where the lobes are muscular and are possibly used as grasping organs.

The dorsal tubercle, when well developed, has the ends of its slit-like aperture coiled in the same sense, so as to form a reversed S. When the stigmata are well-formed and sub-divided, they are characteristically arranged in rows, which are transverse to the pharyngeal folds and lengthwise of the infundibula. As in the other sub-families, in some genera the pharynx fails to develop beyond a very simple state. This is shown to an extreme degree in *Hexacrobylus*.

An outstanding characteristic of this family is the arrangement of the testicular lobes, which are radially arranged in a more or less compact mass situated at the blind end of the usually elongated ovary.

SYPHONOTETHIS Gervais (sens. nov.)

Syn. *Molgula* et *Caesira* auct. (partim)

Apertural lobes fringed or branched in some species at least, probably in all.

Pharynx with 7 folds on each side. Infundibula usually extending into folds, each having many stigmata which are spirally arranged and usually form rows lengthwise of the infundibula. Dorsal lamina with smooth margin, except near posterior end in some cases. Dorsal tubercle with aperture when well developed, usually reverse S-shaped, the horns turned in and coiled, but in type aperture is horseshoe-shaped, with opening between horns directed to right.

Intestinal loop sometimes strongly curved into a secondary loop. A gonad on each side, the left above primary intestinal loop and more or less in secondary, when latter is well formed. Testicular lobes arranged radially at blind end of ovary. A single vas deferens, accompanying ovary and oviduct.

Type species—*S. tumulus* (Quoy et Gaimard).

Sub-gen. *Syphonotethis*

Type species—*S. tumulus* (Quoy et Gaimard).

Infundibula well formed. Stigmata for the most part in rows. Aperture of dorsal tubercle well developed and characteristically bent.

Vas deferens with straight course along middle of an elongated ovary.

Other species are *S. godeffroyi* (Michaelsen), **S. verrucifera* (Ritter and Forsyth, 1917, p. 446) and *S. conchata* (Sluiter).

Molgula forbesi Herdman and *Astropera sabulosa* Pizon should probably be assigned to this group, but they have not been sufficiently described.

Sub-gen. *Callipera* nov. (κάλλος and πήρα)

Type species—*S. pulchra* (Michaelsen).

Infundibula not well developed, but somewhat flattened. Aperture of dorsal tubercle from simple to crescent-shaped.

Vas deferens with tortuous course over inner surface of a short ovary.

A second species is *S. pyriformis* (Herdman). *Molgula crinita* Sluiter also should probably be placed in this sub-genus.

CAESIRA Fleming

Syn. *Ctenicella* Lacaze-Duthiers (partim)
Molgulidium Seeliger (partim)
Molgula auct. (partim)

Apertural lobes fringed or branched.

Pharynx with seven folds on each side. Infundibula extending into folds, each having many stigmata which are spirally arranged, and at the same time form rows lengthwise of the infundibula. Dorsal lamina more or less toothed. Dorsal tubercle with aperture in the shape of an S reversed, the horns usually turned in and coiled.

Intestinal loop somewhat strongly curved into a secondary loop. A gonad on each side, the left above primary but in secondary intestinal loop. Testicular lobes arranged more or less radially at blind end of ovary. A single short vas deferens, not accompanying oviduct.

Type species—*C. dione* (Savigny).

Other species are *C. appendiculata* (Heller), *C. korotneffii* (Drasche), *C. natalensis* (Michaelsen, 1918, p. 2), and *C. cynthiaeformis* (Hartmeyer). From Savigny's account and figures of his species, it is quite clear that it is very close to the species of Heller and Drasche, and, therefore, we may safely infer that it possesses all the generic characters given above, although several minor ones have not yet been demonstrated for it.

Molgula martensi Traustedt may belong here.

LITHONEPHRYA Giard (sens. nov.)

Syn. *Ctenicella* Lacaze-Duthiers (partim)
Molgula et *Caesira* auct. (partim)

Apertural lobes fringed or branched.

Pharynx with 6 or 7 folds on each side. Infundibula extending into folds, each having many stigmata, which are spirally arranged, and at the same time form rows lengthwise of the infundibula. Dorsal lamina more or less toothed. Dorsal tubercle with aperture in the form of a longitudinal slit, the ends of which may turn to opposite sides forming a reversed S.

A gonad on each side, the left above the intestinal loop. In each gonad the oviduct is at the anterior end. Testicular lobes arranged more or less radially at blind (posterior) end of ovary. A single short vas deferens, not accompanying ovary and oviduct.

Type species—**L. complanata* (Ald. and Hanc.).

Other species are **L. tenax* (Traust.), *L. morgatae* (Lac.-Duth.), and **L. canadensis* (Huntsman, 1912, p. 140). *Lithonephrya* exhibits a condition unique for the family, namely a reversal in the orientation of the gonad, the oviduct opening at the anterior or abatrial end of the ovary. In other respects this genus is quite similar to *Caesira*, but with the characteristic features of the latter, such as transverse (to pharynx) arrangement of the stigmata, fringing of apertural lobes, reversed coiling of ends of aperture of dorsal tubercle, and toothing of dorsal lamina, less pronounced.

OLIGOTREMA Bourne

Oral aperture with six branched muscular lobes.

Pharynx without proper folds. No infundibula. Stigmata relatively few, short and more or less curved. Dorsal lamina absent. Dorsal tubercle a simple slit.

A gonad on each side, the left above the intestinal loop. Testicular lobes grouped at blind end of ovary, with a single vas deferens, not accompanying ovary and oviduct.

Type and single species—*O. psammites* Bourne.

HEXACROBYLUS Sluiter

Oral aperture with six large branched muscular lobes.

Pharynx without folds. Dorsal lamina with smooth margin. Dorsal tubercle a simple opening. Tentacles simple or absent.

A gonad on each side, the left above the intestinal loop. Testicular lobes grouped at blind end of ovary, with a single vas deferens, not accompanying ovary and oviduct.

Type species—*H. psammatodes* Sluiter.

The only other species of the genus is *H. indicus* Oka (1913, p. 6).

GAMASTER Pizon

Pharynx with seven longitudinal bars on each side in place of folds. Infundibula in rows corresponding to the bars, each consisting of one or two long spirally coiled stigmata. Condition of dorsal lamina and dorsal tubercle not known.

A single gonad, situated on the right side. Testicular lobes arranged radially at blind end of ovary. Vas deferens (or vasa deferentia?) not accompanying ovary and oviduct.

Type species—*G. dakarensis* (Pizon).

The only other species is *G. woermanni* (Michaelsen), described by Michaelsen in 1914 (p. 423) as *Eugyra w.* Its affinities are, however, definitely with Pizon's species. *Gamaster* parallels the typical *Eugyrinae* both in the condition of the stigmata and in the failure of the pharyngeal folds to develop.

Uncertain Genera

Hartmeyer (1914, p. 8) has formed the genus *Molgulina* for those species, formerly assigned to the genus *Molgula* or *Caesira,* which have a small number of longitudinal bars on each fold and the infundibula flattened out. This group, as well as the genus *Molgula*, as the latter would then be, seems quite heterogeneous and unnatural. The type, *M. eugyroides* (Traust.) possesses very curious gonads, and on this basis the genus doubtless will be a valid one, but the structure of these gonads has not yet been sufficiently described.

Similarly it has been impossible to consider *Ascopera* Herdman, and *Bathypera* Michaelsen in the classification here proposed, owing to their structure being so imperfectly known.

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